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CURRENT ALTERNATIVE ENERGY RESEARCH AND DEVELOPMENT IN ILLINOIS

June 1984

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Illinois Department of
Energy and Natural Resources

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CURRENT ALTERNATIVE ENERGY
RESEARCH AND DEVELOPMENT
IN ILLINOIS

June 1984

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and Natural Resources

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PREFACE

To maintain its leadership in industry and agriculture, Illinois needs dependable energy sources. The prospect of having renewable energy resources is especially attractive to energy consumers faced with rising prices of conventional energy sources and uncertain supplies of oil and gas. Many new technologies are being developed and demonstrated that promise efficient use of these virtually inexhaustible resources.

The purpose of CURRENT ALTERNATIVE ENERGY RESEARCH AND DEVELOPMENT IN ILLINOIS is to inform researchers, policy makers and interested citizens of the status of alternative energy-related research, development and demonstration projects within Illinois. The directory will be issued biannually by the Illinois Department of Energy and Natural Resources in an effort to consolidate within one document data and information on current activities and to facilitate communication among those who are involved in similar projects.

Together, we need to apply Illinois' abundant academic and technological expertise to assure continuing and affordable supplies of energy.

Michael B. Witte

Michael B. Witte, Director
Illinois Department of Energy
and Natural Resources

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INTRODUCTION

This directory constitutes an inventory of recent activities involving research, development and demonstration projects of nonfossil, nonnuclear energy sources. Projects discussed in the directory were either in process in May 1984 or had been completed after November 1983.

The information and data were obtained directly from the project participants. Several methods were used to identify possible contributors:

- review of ENR mailing lists for those expressing an interest in alternative energy;
- inventory of known contractors and applicants to state alternative energy programs;
- computer searches on the U.S. Department of Energy RECON Data Base in the Research-in-Progress file; and
- reviews of directories, reports, newsletters, newspapers, summary publications and conference proceedings for Illinois projects.

Omissions inevitably occur in compiling a document of this type. These omissions and other possible errors should be brought to the attention of the editor for correction in the next edition.

Entries are arranged by broad subject categories in the order listed in the Table of Contents. Within each category, entries are alphabetical by the performing organization and alphabetical by title where there is more than one entry for an organization. Entries are indexed by title, contributor, research organization and project site.

Reports on 89 alternative energy projects are included and fall into nine major categories. Forty percent of the projects involve bioenergy and a third are solar related. The topics with actual numbers of reports are as follows:

	Number
Bioenergy	37
Solar Heating and Cooling	24
Solar Photovoltaics	2
Solar Thermal and Advanced Technologies	3
Geothermal and Ocean Thermal	3
Wind Energy	5
Waste Heat and Materials Recovery	6
Energy Storage	7
Regulations, Surveys and Planning	2
TOTAL	89

BIOENERGY: BIOMASS RESOURCES

Title: Hydrocarbon-Producing Plants as Potential Multi-Use Crops

Performing Organizations: Northern Agricultural Energy Center

Principal Investigator(s): Marvin O. Bagby, Merle E. Carr
USDA-Northern Regional Research Center
1815 N. University St.
Peoria, IL 61614 (309) 685-4011, ext. 531

Sponsoring Organization: USDA-ARS

Project Location: Peoria, Illinois

Project Summary

Whole-plant specimens of 625 species were collected. Of these, 350 were evaluated for their potential as energy-producing crops. Oil and hydrocarbon from 85 selected species were partially characterized for liquid classes, for yields of fatty acids and unsaponifiable matter, for rubber, gutta, and/or waxes in hydrocarbon, by IR and ^{13}C NMR, and for MW and MW distribution of rubber and gutta for GPC. Of the 350 species 35 were identified for future study. Promising species yielded as much as 10% oil (Pinus albicaulis), 26% polyphenol (Acer ginnala), 2.3% hydrocarbon (Pittosporum tobira), and 23% apparent protein (Verbesina encelioides), on a dry, whole- plant basis. Two new sources of gutta were discovered (Garrya flavescene and G. Wrightii). A GPC technique was developed to quantitate rubber. For a heritability study, 78 leaf samples of Asclepia syriaca were analyzed for oil, polyphenol, hydrocarbon, and protein. For 12 USDA plant scientists, 625 sugar crop samples (1982 harvest) were analyzed for sugars and 580 samples (1980 harvest) for lignin and cellulose. Five species in 25-pound quantities were collected for gasification and biomass quality study for a cooperating university. Hydropulping studies of oil- and hydrocarbon- producing plants (e.g., milkweed, guayule, and sunflower) after solvent extraction were conducted to enhance their multipurpose usefulness.

Projected Completion Date

N/A

Related Publications

Carlson, K.D., R.L. Cunningham, and A.I. Herman. "Sweet sorghum grown on sludge-amended stripmine soil: A preliminary look at yields, composition, and ethanol production." Trans. Ill. State Acad. Sci., 76(3 and 4):111-122.

Carlson, K.D., M.E. Carr, R.L. Cunningham, M.O. Bagby, and D.M. Palmer. "Lignin analyses on sweet sorghum samples." Trans. Ill. State Acad. Sci., 76(3 and 4):265-269.

Title: C-4 Grasses with Legumes: An Energy-Efficient Biomass System

Performing Organizations: Departments of Agronomy and Forestry
University of Illinois

Principal Investigator(s): C. James Kaiser
Dixon Springs Agricultural Center
Simpson, Illinois 62985 (618) 695-2441

Timothy A. White
110 Mumford Hall
1301 W. Gregory Drive
Urbana, Illinois 61801 (217) 333-8641

Sponsoring Organization: The Bio-Energy Council
1625 Eye St., N.W., Suite 825A
Washington, DC 20006

Project Location: Dixon Springs Agricultural Center
Simpson, Illinois 62985

Project Summary

Converting solar energy into biomass for fuel is theoretically most energy-efficient when species of a high photosynthetic capacity are grown and nitrogen is furnished via symbiotic fixation. Warm season grasses with the C-4 photosynthetic pathway will outyield cool season types that possess less efficient C-3 pathway.

The overall objective of the project is the evaluation of grass-legume biomass production systems that would minimize erosion in southern Illinois and the central U.S. transitional climatic zone. It is anticipated that specie systems of warm season grasses and winter legumes may be more productive and energy-efficient than traditional cool season grass-legume combinations.

Preliminary research indicates that of a number of warm season grasses eastern gamagrass (Tripsacum dactyloides) is highly productive, drought tolerant and winter hardy. A number of selections and ecotypes are planted at the Dixon Springs Agricultural Center in southern Illinois and are available for increase by propagation. The goal is to determine those lines with greatest productivity potential as a cellulose source for alcohol production and especially determine those for establishing nitrogen-fixing winter legumes following each production season. For comparison a cool season production grass (Festuca arundinacea or Pharlaris arundinacea) in combination with cool or warm season legumes (i.e., Trifolium pratense or Lespedeza cuneata) and also a combination of L. cuneata with gamagrass will be grown.

Projected Completion Date

Project is funded through 1983

Related Publications

None to date

Title: Energy Production from Direct-Seeded Woody Biomass

Performing Organization: Department of Forestry
University of Illinois

Principal Investigator(s): Gary L. Rolfe and Jeffrey O. Dawson
110 Mumford Hall
1301 W. Gregory Drive
Urbana, Illinois 61801 (217) 333-2770

Sponsoring Organization: Illinois Agricultural Experiment Station
McIntire-Stennis Research Program

Project Location: Dixon Springs Agricultural Center
Simpson, Illinois 62985

Department of Forestry,
University of Illinois
Urbana, Illinois 61801

Project Summary

Establishment costs of high-density, short-rotation woody biomass energy plantations are one of the dominant features found in economic analyses which may limit the adoption of this concept by the private sector. Especially overwhelming is the cost of seedling transplants. Direct seeding of selected biomass species may offer one alternative that could reduce these costs and shorten the time required for economic viability of woody plantation bioenergy, particularly in the private sector.

The objectives of this work are directed at answering the following questions:

1. Which species are most suitable for direct seeding? What seed treatments and site preparations are necessary? What planting equipment and techniques are best for direct seeding of trees?

2. What weed control measures will be required when direct seeding?

3. Do seedlings establish equally well on all sites? Are some species better adapted to some sites than others?

4. What effect does population density have on establishment and short-term yields? and

5. What impact does high-density woody biomass have on soil nutrient reserves? Do they respond similarly to N, P and K on all sites?

Efforts are being directed toward utilizing commercially available equipment for planting seed in order to limit capital expenditures necessary for adoption of this technique by the private sector.

Preliminary work has included greenhouse herbicide trials which focus on providing adequate weed control while maintaining survival and growth rates of desired tree species. Both aspects are important to tree establishment by direct seeding in the field.

Greenhouse studies evaluating pre-germination seed treatments have included temperature stratification using cold, warm, and an alternation of both cold and warm temperatures. Seed coat scarification by chemical and mechanical means were also tested. Success has been measured by monitoring percent germination and the rate of germination.

Fluid drilling of seeds is a planting procedure currently receiving attention. Pre-germinated seeds are suspended in a gel-like substance when field planted. The risk of germination is overcome. Additions to the "gel" may promote survival and growth of tree seedlings. Protective chemicals, growth hormones, nutrients, and inoculation with N-fixing bacteria have been successfully utilized by various growers.

Projected Completion Date

Funding has been requested of the McIntire-Stennis program through 1986 with coppice harvest evaluations extending somewhat beyond this date.

Related Publications

White, T.A., G.L. Rolfe and D.R. Bluhm. "Energy production from direct-seeded woody biomass." Ill. Agr. Exp. Sta. DSAC 9:249-252, 1981.

White, T.A. and G.L. Rolfe. "Tolerance of direct seeded black locust (Robinia pseudoacacia L.) to herbicides." Ill. Agr. Expt. Sta. For. Res. Rep. (in press, 1982).

White, T.A. and G.L. Rolfe. "Comparative energy costs of stem cuttings, seedlings, and seeds as propagules in woody biomass plantations." Biomass. (in press, 1983.)

Title: Woody Biomass for Energy Using Municipal Sludge-Amended Land

Performing Organizations:	Department of Forestry University of Illinois In cooperation with the Metropolitan Sanitary District of Greater Chicago and the Illinois Institute of Natural Resources
Principal Investigator(s):	Gary L. Rolfe, Stuart L. Warren and J.M. Edgington 110 Mumford Hall 1301 W. Gregory Drive Urbana, Illinois 61801 (217) 333-2770
Sponsoring Organizations:	The Bio-Energy Council 1625 Eye St., N.W., Suite 825A Washington, D.C. 20006 Metropolitan Sanitary District of Greater Chicago 100 E. Erie Street Chicago, Illinois Illinois Department of Energy and Natural Resources 325 West Adams Street Springfield, Illinois 62706
Project Location:	Metropolitan Sanitary District of Greater Chicago P.O. Box 457 Canton, Illinois 61520

Project Summary

The major objective of this study is to assess the feasibility of solar energy conversion through the production of woody plant biomass over short rotations on municipal sludge-amended strip mined land.

Specifically this research will:

1. determine optimum species and spacing alternatives
2. evaluate growth of woody biomass
3. determine optimum rate of sludge application
4. determine the uptake and distribution of heavy metals
5. develop management techniques

A systems approach with a biological basis has been chosen to accomplish this research effort considering environmental and site impacts along with establishment, maintenance and production techniques.

To date, plots of five species (black locust, hybrid poplar, autumn olive, black alder and sycamore) have been planted. Soil nutrient pools have been assessed at each site. Vegetative nutrient analysis of initial growth as well as extensive analysis of the incorporated sludge have also been accomplished.

Preliminary results of growing short rotation tree species on sludge-amended strip-mine spoil have been determined. After analyzing initial data and evaluating the information, several changes in project procedures have been made without sacrificing project objectives. These changes were made as part of the development of management techniques to more effectively and efficiently use degraded land and marginal cropland. The following is a summary of the procedural changes since the 1983 report:

Species - Black locust, hybrid poplar and sycamore were expanded to include autumn olive. (Black alder was deleted from plantings.)
Spacing - Spacing was changed to 24 x 30 inches and 24 x 60 inches to accommodate equipment limitations.
Plot size - Plot size was reduced from .5 acre to .25 acre due to limited acreage available at the site and to a 100 percent increase in seedling costs.
Weed control - Some herbicides provided inadequate weed control and were discontinued. Other herbicides required adjustments of application rates in order to gain adequate weed control.

The following is a summary of the results after the second growing season:

Optimum rates of sludge application - The total volatile solids of sludge indicated the actual rate of sludge applied to the site was approximately 350 tons/acre rather than the expected 150 tons/acre. The sludge was applied to an average depth of 12 inches over the site and had the consistency of wet concrete which severely hampered incorporation. Consequently, the planting mixture had a low percentage of mine-spoil. This inability to adequately prepare the site for planting coupled with the abnormally high amount of spring rainfall, the moisture barrier formed as the sludge dried, and the high salts content of the sludge contributed to virtually a complete failure of the 1980 plantings. Subsequent plantings (1981, 1982 and 1983) have been successful due to more intensive site preparation, better weather conditions, and the probable leaching of the salts.

High rates (approximately 350 tons/acre) of sludge were applied to test plots and evidence suggests that this rate is deleterious to tree establishment, at least in the first year after sludge application.

An additional greenhouse study was made using planting mixtures of various sludge loading rates (0, 50, 100 and 150 tons/acre) and mine-spoil. The results of the study will be correlated with field plantings established in 1983 to determine the optimum sludge loading rate.

Laboratory analysis of the soil and vegetation for nutrients and heavy metals has been completed for the 1982 sampling. The correlation with the 1981 data is currently being made.

The spring 1983 planting has been completed and is the last planting planned for this project. All species in all plantings will be harvested in the fall of 1984 after which a final analysis will be made.

Projected Completion Date

Project is funded through May 1984.

Related Publications

None to date.

Title: Woody Biomass Production on Reclaimed Strip Mine Land in Southern Illinois

Performing Organizations: Department of Forestry
University of Illinois

In cooperation with

Southern Illinois Coal Corporation
Percy, Illinois 62272

Principal Investigator(s): Gary L. Rolfe and Timothy A. White
110 Mumford Hall
1301 W. Gregory Drive
Urbana, Illinois 61801 (217) 333-2770

Sponsoring Organization: Southwestern Illinois Coal Corporation
Percy, Illinois 62272

Project Location: Captain Mine
Southwestern Illinois Coal Corporation
Percy, Illinois 62272

Project Summary

Research has been initiated to study the establishment, yield and site impact of woody biomass energy plantations on a variety of reconstructed strip mine sites in southern Illinois. Three species (autumn olive, black locust and sycamore) have been planted on three sites each of which represents a specific soil reconstruction technique. A total of 75,000 seedlings were planted across 15 acres in the spring of 1982. Different fertility levels will be superimposed on test plots to determine the effect of fertilization upon growth and yield of woody biomass.

Projected Completion Date

Coppice harvests will be made until approximately 1990.

Related Publications

None to date

Title: Woody Biomass Production Through Solar Energy Conversion

Performing Organization:	Department of Forestry University of Illinois
Principal Investigator(s):	Gary L. Rolfe 110 Mumford Hall 1301 W. Gregory Drive Urbana, Illinois 61801 (217) 333-2770
Sponsoring Organization:	U.S. Department of Energy through Union Carbide Corporation - Oak Ridge National Laboratory, Oak Ridge, TN 37830 Illinois Agricultural Experiment Station Hatch Research Program
Project Location:	Dixon Springs Agricultural Center Simpson, Illinois 62985 Phillips Tract Biological Research Area Urbana, Illinois 61801

Project Summary

The major goal of this project is to evaluate the feasibility of using marginal agricultural, forest and other lands for producing woody material for energy conversion processes. A systems approach has been used which emphasizes the ultimate adoption of biomass producing systems by the small non-industrial landowner.

The specific objectives of this work are:

1. evaluate species, spacing and rotation length (cutting cycle) alternatives;
2. determine economically sound stand establishment and maintenance requirements for biomass plantings;
3. determine production capabilities for a range of site qualities with no initial fertilization;
4. evaluate the impacts of intensive silvicultural systems upon native soil nutrient pools; and
5. develop energy budgets for various short rotation woody biomass production scenarios.

Stand densities studied range from 21,500 to 191,350 stems per hectare. Rotation lengths ranging from two to four years are being examined. Autumn olive (Elaeagnus umbellata Thunb.), black locust (Robinia pseudoacacia L.) and american sycamore (Platanus occidentalis L.) have the greatest seedling rotation productivity of the species studied thus far with yields in some instances exceeding 9 metric tons per hectare-year. These yields have been achieved on marginal land receiving no fertilization and only establishment year irrigation. Energy balances can also be high - in some cases as high as 23 to 1.

Coppice production over two growing seasons has consistently exceeded yields from 1-0 seedling growth over 4 years. Two years of coppice growth has reached maximums of over 19 dry metric tons/hecatre-year. High coppice yields improve the economic profitability of short rotation wood production systems. Several harvests can occur over a plantation's lifetime. Wood is supplied over several years without the cost of re-establishment. Research is needed to investigate the number of coppice harvests possible while simultaneously sustaining production levels. Proper coppice management could provide maximum wood yields and economic returns.

Recommendations for Illinois and the Midwest region regarding species, spacings, and rotation lengths for short rotation wood production systems are as follows:

species;	black locust
	autumn olive
	American sycamore
spacings;	0.46m x 0.76m
	0.61m x 0.76m
rotation lengths;	3 years
	4 years
	general range of 4-10 years

Other areas requiring further investigation include site impacts, particularly regarding long-term soil fertility. Plantation establishment by directly seeding trees reduces the cost of wood production. The cost of seeds is much lower than seedlings or cuttings. Development of the direct seeding concept for recommended species could improve the profitability of short rotation woody biomass plantations by 5-10 times.

Projected Completion Date

DOE funding scheduled to terminate in 1984. Coppice evaluations will continue beyond this date.

Related Publications

Chow, P., G.L. Rolfe, T.A. White and C.S. Lee. "Energy values of juvenile sycamores." Ill. Research 22(4):12-13, 1980.

Chow, P., G.L. Rolfe, C.S. Lee and T.A. White. "The chemical properties of 2-year-old deciduous species." J of App Poly Sci, Symposia series. (in press, 1982).

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Dawson, J.O., T.A. White, R.A. Herendeen and P.J. Dzialowy. "Accretion of nitrogen in soil of a young plantation of *Robinia pseudoacacia*." Ill. Agr. Expt. Sta. For. Res. (in press, 1982).

Rolfe, G.L. and T.A. White. "Capturing the sun's energy in woody biomass." *Ill. Research* 21:4-5, 1979.

White, T.A., G.L. Rolfe, J.J. Faix and R.W. Zimmerman. "Pilot studies of woody biomass for energy." Ill. Agr. Expt. Sta. DSAC 7:221-225, 1979.

White, T.A. and G.L. Rolfe. "Stand establishment and maintenance of woody biomass species - 1979 herbicide trials." Ill. Agr. Expt. Sta. DSAC 8 171-175, 1980.

White, T.A., G.L. Rolfe and D.R. Bluhm. "Establishment of woody biomass plantations in the midwest: 1980 herbicide trials." Ill. Agr. Exp. Sta. DSAC 9:236-246, 1981.

White, T.A., G.L. Rolfe and D.R. Bluhm. "Yield of six woody biomass species during a two-year establishment rotation in southern Illinois." Ill. Agr. Exp. Sta. DSAC 9:246-248, 1981.

White, T.A., G.L. Rolfe and D.R. Bluhm. "The energy balance of intensively cultured autumn olive for biomass production." Ill. Agr. Exp. Sta. DSAC 9:253-259, 1981.

White, T.A., G.L. Rolfe and D.R. Bluhm. "Effects of herbicides on tolerance of woody biomass species and control of weeds in southern Illinois: 1980 herbicide trials." Ill. Agr. Exp. Sta. For. Res. Rep. (in press, 1982).

White, T.A., G.L. Rolfe and D.R. Bluhm. "Effects of some preemergent herbicides on survival and tolerance of various woody biomass species. I: 1979 herbicide trials." Ill. Agr. Exp. Sta. For. Res. Rep. (in press, 1982).

BIOENERGY: CONVERSION TECHNOLOGIES

Title: Biomass Conversion Environmental Program

Performing Organization: Argonne National Laboratory

Principal Investigator(s):
H. Chang and R. Niemann
ANL
9700 S. Cass Ave., Bldg. 362
Argonne, Illinois 60439
(312) 972-7340
(312) 972-6256

Sponsoring Organization:
Department of Energy
Biomass Environmental Technology

Project Location: Argonne National Laboratory with subcontracts to Battelle Columbus Laboratory and Pacific Northwest Laboratory

Project Summary

This program covers environmental research on biomass gasification (a thermo-conversion process) and bioconversion. Top-priority problems that could impact the national biomass conversion industry are considered. Environmental research on gas, liquid and solid effluents emitted from DOE-sponsored projects is emphasized. Environmental control technology (ECT) and designs of gasifiers with minimum environmental impacts are both considered as means for mitigating pollution.

Projected Completion Date

Ongoing program

Related Publications

Bibliography available on request

Title: Ethanol Production via Fungal Decomposition and Fermentation of Biomass

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Antonios A. Antonopoulous
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Sponsoring Organization: U.S. Department of Energy
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Project Location: Argonne National Laboratory

Project Summary

Strains of the fungal genus *Fusarium* can decompose cellulose, hemicelluloses, pectic substances, lignin, and other plant constituents, and can ferment both hexoses and pentoses to ethanol. Therefore, the purpose of this project is to: (a) isolate and develop new and more effective lignocellulolytic and glucose- and xylose-fermenting *Fusarium* strains; (b) optimize the biomass sacharification and fermentation by *Fusarium* strains for the purpose of maximum ethanol yield; (c) identify and quantify the celluloytic and fermenting enzymes released by the selected strains; (d) identify and evaluate the synergistic and/or complementary celluloysis of biomass by selected strains of Fusaria and other microbes; and (e) develop an immobilized cell bioreactor for the continuous fermentation of monosaccharides by *Fusarium* strains to produce ethanol.

Research efforts at Argonne National Laboratory have indicated that the amount of ethanol produced from the fermentation of glucose by selected *Fusarium* strains is comparable to that yielded by yeast and, moreover, *Fusarium* strains can effectively hydrolyse cellulose and ferment five-carbon sugars (i.e., xylose).

Projected Completion Date

Ongoing program.

Title: Bioconversion of Renewable Resources to Methane

Performing Organization: Institute of Gas Technology

Principal Investigator(s): David P. Chynoweth, Ph.D.
Assistant Director
Bioconversion Research
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616 (312) 567-3715

Sponsoring Organization: Gas Research Institute

Project Location: Chicago, Illinois

Project Summary

This project represents a consolidation of several previous projects on the study of biological gasification of kelp, several species of land-based biomass, and water hyacinth and primary sludge blends. The objective of this research is to develop efficient processes for the conversion of biomass and organic wastes to methane and other useful products at costs competitive with those of other resources. This work is part of an overall Gas Research Institute-sponsored research program to evaluate the technical and economic feasibility of producing methane from a broad spectrum of biomass species and wastes that have potential for economic production and collection in large quantities. The goal of the research proposed here is to develop gasification processes for four prototype feedstocks which warrant separate investigation based on differences and physical and chemical properties. The specific objectives for each feedstock are:

1. to develop an understanding of rate- and yield-limiting reactions and factors influencing process stability, and

2. to define and develop a biogasification process scheme and associated data base to the extent necessary for design and operation of a larger-scale experimental test unit.

The results of previous research on several feed types have demonstrated that the highest conversion (and associated methane yield), most rapid process kinetics, and greatest process stability can be obtained in reactors that achieve high solids and microorganism retention. We have further concluded that the choice of reactor design and mode of operation are highly dependent upon the physical and chemical characteristics of the feed, especially the concentration of particulate solids.

Our current research is focused on four prototype species selected on the basis of their particulate solids concentration and lignin content. We feel that the process developed for each group will be applicable to other feeds with similar properties. The prototype species selected are: water hyacinth (low solids, freshwater species); primary sludge (low solids, waste); kelp (medium solids, freshwater species); sorghum (high solids, low lignin, herbaceous species, crop residue); and hybrid poplar (high solids, high lignin, woody species).

The following achievements made thus far are worth highlighting. An anaerobic biogasification potential (ABP) bioassay has been refined and applied to several herbaceous and woody species as well as kelp. Methane yields in the range of 4 to 6 SCF/lb VS added were obtained for most herbaceous and several woody species without pretreatment. These yields are substantially higher than reported previously for conventional digestion of woody species. One species, sorghum, exhibited methane yields in the range of 4.5 to 6.4 SCF/lb VS added, corresponding to a reduction in organic matter of 74 percent to 94 percent. A kinetic model was developed for the biogasification of water hyacinth, primary sludge, and blends on these feeds. A novel upflow solids digester which achieves higher solids than liquid retention times resulted in 20 percent to 25 percent higher conversions of the blend of water hyacinth and sludge to methane. The same upflow solids digester has resulted in the best biogasification achieved to date for particulate biomass at mesophilic temperatures. With kelp, methane yields exceeding 6 SCF/lb VS added have been achieved at loadings up to 0.5 lb VS/ft^3-day. Research is continuing to focus on further optimization of the upflow solids reactor for kelp and water hyacinth, and on development of new high solids digestion processes for sorghum and woody species.

Projected Completion Date

Not yet determined

Related Publications

Chynoweth, D.P. "Anaerobic digestion of aquatic and terrestrial biomass." Presented at the Energy-Sources Technology Conference, Houston, TX, February 1983.

Fannin, K.F., V.J. Srivastava, D.P. Chynoweth, and K.T. Bird. "Effects of the interaction between biomass composition and reactor design on anaerobic digester performance." In symposium papers, Energy From Biomass and Wastes VII, sponsored by the Institute of Gas Technology, Lake Buena Vista, FL, January 1983. In press.

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Jerger, D.E., M. Novil, and D.P. Chynoweth. "Bioconversion of woody biomass as a renewable source of energy." Biotech. Bioeng. Symp. No. 12: 233-248, 1982.

Jerger, D.E., J.R. Conrad, K.F. Fannin, and D.P. Chynoweth. "Biogasification of woody biomass." In symposium papers, Energy From Biomass and Wastes VI, sponsored by the Institute of Gas Technology, Lake Buena Vista, FL, January 1982, pp. 341-367.

Fannin, K.F., V.J. Srivastava, and D.P. Chynoweth. "Unconventional anaerobic digester designs for improving methane yields from sea kelp." In symposium papers, Energy From Biomass and Wastes VI sponsored by the Institute of Gas Technology, Lake Buena Vista, FL, January 1982, pp. 373-396.

Ghosh, S., D.P. Chynoweth, and D.L. Klass. "A parameter study of methane production from sea kelp *Macrocystis Pyrifers* by anaerobic digestion." *J. Chemical Technology and Biotechnology*, 31: 791-807, 1981.

Chynoweth, D.P., S. Ghosh, and D.L. Klass. "Anaerobic digestion of kelp." *Biomass Conversion Processes for Energy and Fuels*, eds. O.R. Zaborsky and S. Sofer, Plenum Publishing Corporation, New York, Chapter 18: 315-337, 1981.

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Forro, J.R., D.P. Chynoweth, and M.R. Hart. "Kelp processing and biomethanation technology." Proceedings of the 15th Intersociety Energy Conversion Engineering Conference, Seattle, August 1980.

Chynoweth, D.P. and V.J. Srivastava. "Methane production from marine biomass." Paper presented at the International Symposium on Biogas, Microalgae, and Livestock Wastes - 1980, Taipei, Taiwan, R.O.C., September 1980.

Chynoweth, D.P. "Energy from marine biomass: gasification process development." Paper presented at the Bio-Energy '80, Atlanta, April 1980.

Ghosh, S., D.L. Klass, and D.P. Chynoweth. "Bioconversion of sea kelp *Macrocystis Pyrifers* to methane." Paper presented at the International Symposium of Marine Algae of the Indian Ocean Region, Central Salt and Marine Chemical Research Institute, Bhavnager, India, January 9-12, 1979.

Chynoweth, D.P. "Anaerobic digestion of marine biomass." Paper presented in Proceedings of a Seminar on Biomass Energy for City, Farm and Industry: *Biomass and Alcohol Fuels Production*, J.G. Press, Emmaus, PA, 1979, pp. 185-192.

Klass, D.L., S. Ghosh, and D.P. Chynoweth. "Methane production from aquatic biomass by anaerobic digestion of giant brown kelp." *Process Biochemistry* 14: 18-22, 1979.

Chynoweth, D.P., D.L. Klass, and S. Ghosh. "Biomethanation of giant brown kelp *Macrocystis Pyrifera*." In symposium papers, *Energy From Biomass and Wastes*, sponsored by Institute of Gas Technology, Washington, DC, August 1978, pp. 229-257.

Title: Biogasification of Walt Disney World Biomass Waste Blend

Performing Organization: Institute of Gas Technology

Principal Investigator(s): David P. Chynoweth, Ph.D.
Assistant Director
Bioconversion Research
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616 (312) 567-3715

Sponsoring Organization: Gas Research Institute

Project Location: Orlando, Florida

Project Summary

Research is in progress to evaluate water hyacinth ponds for secondary and tertiary wastewater treatment, optimize operation of hyacinth ponds for high biomass yields, and develop and optimize an anaerobic digestion process for conversion of primary sludge and harvested water hyacinth to methane. Results obtained thus far indicate that effective wastewater treatment is obtained as measured by removal of suspended solids and biochemical oxygen demand (BOD), nitrogen and phosphorus. Average annual yields of 25 dry tons per acre per year have been obtained. Anaerobic digestion experiments have demonstrated that primary sludge and water hyacinth can be effectively digested either separately or as blends and without pH control or nutrient addition. Methane yields of 8 and 3 SCF/lb VS added, respectively, have been obtained for primary sludge and water hyacinth. Methane yields from a novel upflow reactor were about 20 percent higher than those observed in a conventional stirred tank reactor. A 160 ft^3 experimental test unit is being installed at the experimental test facility located at Walt Disney World. This unit will be used to evaluate materials handling and other parameters related to process scale-up. The results of this conversion research and related work on hyacinth productivity will provide a basis for optimization and technical and economic evaluation of the total water hyacinth wastewater treatment energy conversion system. It is anticipated that the ETU will also be useful for scale-up of anaerobic digestion processes on other feedstocks currently under study in the laboratory.

Projected Completion Date

Not yet determined

Related Publications

Chynoweth, D.P., B. Schwegler, D.A. Dolenc, and K.R. Reddy. "Wastewater reclamation and methane production using water hyacinth and anaerobic digestion." Presented at the Tenth Annual Energy Technology Conference, Washington, DC, February 1983.

Chynoweth, D.P., S. Ghosh, M.P. Henry, and V.J. Srivastava. "Biomethanogensis of water hyacinth and primary sludge." Biotech. Bioeng. Symp. 12: 381-398, 1982.

Chynoweth, D.P., S. Ghosh, and M.P. Henry. "Biogasification of blends of water hyacinth and domestic sludge." Proceedings of the 1981 International Gas Research Conference, sponsored by the Gas Research Institute, September 1981, pp. 742-755.

Title: Evaluation of the GRI Walt Disney World Water Hyacinth/Sludge Blend Program for the Presence of Undesirable Bacteria and Viruses

Performing Organization: Institute of Gas Technology

Principal Investigator(s): Kerby F. Fannin, Ph.D.
Manager, Microbiological & Environmental Research
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616 (312) 567-3941

Sponsoring Organization: Gas Research Institute

Project Location: Chicago, Illinois

Project Summary

The presence of pathogenic microorganisms indigenous to the Walt Disney World water hyacinth/sludge water reclamation process is under evaluation by assaying bacteria and viruses in samples taken throughout the process at specific intervals during the study period. The survival of certain viruses and bacteria during anaerobic digestion and of the water hyacinth/sludge blend are also under evaluation. Anaerobic digesters are being seeded with the microorganisms and these digesters are operated under different conditions, solids residence times, hydraulic retention times and temperature. The survival of these seeded organisms is being evaluated over time. The results of this study will be utilized to determine the potential survival of pathogenic organisms in the system as well as to determine operating conditions which result in least survival of pathogens.

Projected Completion Date

Not yet determined

Related Publications

None

Title: Fundamental and Applied Research on Stabilization of Sewage Sludge by Two-Phase Anaerobic Digestion

Performing Organization: Institute of Gas Technology

Principal Investigator(s): Sambhunath Ghosh
Manager, Bioengineering Research
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616

Sponsoring Organization: U.S. Environmental Protection Agency
(Grant CR 809982-01-1)

Project Location: IGT's Chicago headquarters

Project Summary

The objective of this research is to develop an advanced digestion process to stabilize and biogasify sewage sludges at higher overall rates and net energy production efficiencies than are achieved by conventional high-rate digestion. The work is being coordinated with the South Essex Sewerage District projects.

The fundamental research consists of bench-scale anaerobic digestion experiments using complete-mix digesters to find the effects of temperature, pH, oxidation-reduction potential, hydraulic retention time, solids retention time, and loading rate on the performance of acidogenic and methanogenic stages in the digestion process.

In addition, IGT is studying the degradation efficiencies of selected sludge-substrate components which could be difficult to hydrolyze during acidogenic digestion.

In the applied research part of this work, IGT will explore various advanced digester designs and will investigate selected control strategies to minimize shocks to process cultures caused by probable episodes of high metal toxicity at the South Essex Sewerage District plant.

Projected Completion Date

September 1984

Related Publications

Ghosh, S., M.P. Henry and A. Sajjad. "Novel Two-Phase Anaerobic Gasification with Solid-Bed Acid Digestion in Tandem with Fixed-Film Methane Fermentation" Paper presented at International Gas Research Conference, London, England, June 13-16, 1983.

Ghosh, S., M.P. Henry, P.B. Tarman, V.H. DeProost, P. Pipyn and J.P. Ombregt. "Stabilization of High-Cod Industrial Wastes by Two-Phase Anaerobic Digestion to Maximize Net Energy Production" Proceeding of Industrial Wastes Symposia, Water Pollution Control Federation 56th Annual Conference, Atlanta, Georgia, October, 1983.

Ghosh, S., A. Sajjad, M.P. Henry and R.A. Bleakney. "Two-Stage Upflow Anaerobic Digestion of Concentrated Sludge" Presented at 5th Symposium on Biotechnology for Fuels and Chemicals, Gatlinburg, Tennessee, May 10-13, 1983.

Title: Gasification of South Essex Sewage District Sludge

Performing Organization: Institute of Gas Technology

Principal Investigator(s):
Sambhunath Ghosh
Manager, Bioengineering Research
Institute of Gas Technology
3424 South State Street
Chicago, IL 60616

Sponsoring Organizations:
Boston Gas Company
Brooklyn Union Gas Company
Haverhill Gas Company
Bay State Gas Company
Valley Resources, Inc.
Cogenic Energy Systems, Inc.

Project Location: IGT's Chicago headquarters with a pilot plant at Salem, Massachusetts

Project Summary

This work is being done in several parts with the first part, "Bench-Scale Studies," being done in Chicago. This part is nearly completed. A stirred-tank acid-stage digester was operated in tandem with a stirred-tank methane-stage digester. An anaerobic acidogenic culture was developed and acclimated to Salem sludge. A methanogenic culture was subsequently developed and likewise acclimated. Overall, the system produced methane yields which averaged 6 SCF/lb of volatile solids added at hydraulic residence times averaging 8 days.

Following these tests, two bench-scale upflow-type acid- and methane-stage digesters were designed, installed and operated with Salem sludge. Overall, this system produced methane yields of about 5 and 7 SCF/lb VS added at HRT's of 5 and 7 days, respectively. The digested sludge produced in this system was dryer than that found in the stirred-tank system first examined; a significant process advantage.

Projected Completion Date

April 1985

Related Publications

None

Title: Energy-Saving Methods for Recovery of Usable Protein from Alcohol or Methane Fermentation Media

Performing Organization: Northern Agricultural Energy Center

Principal Investigator(s): Marvin O. Bagby, Jerold A. Bietz
USDA-Northern Regional Research Center
1815 N. University St.
Peoria, IL 61604 (309) 685-4011, ext. 531

Sponsoring Organization: USDA-ARS

Project Location: Peoria, Illinois

Project Summary

Residues from fermentation of hard and soft wheats and wheat flours were fractionated into distillers' grains, centrifuged solids, and distillers' solubles. Solid fractions were enriched in protein and lysine, but had reduced breadmaking properties. Soluble fractions from corn steep water and sorghum and wheat stillage, processed by untrafiltration and reverse osmosis, yielded permeates low in nitrogen and dissolved solids. Blended foods were formulated containing corn meal, soy flour, nonfat dry milk, and high-protein corn distillers' dried grains (CDG). Reduced flavor acceptability was noted for these products, but improvement was achieved through extraction. Fiber content of CDG blends was reduced by dry milling and sieving. These studies suggest that products containing up to 10% CDG will be acceptable in blended foods. Studies of solubility and of sulfur amino acids in proteins from corn gluten meal (CGM), a product or wet milling, indicated that disulfides are converted to S-sulfo groups during SO_2 steeping; amounts of -SH, -SS-, and $-SSO_3-$ in products were determined. Coextrusion of CGM with soybean meal gave highly textured nutritious products having poultry meat appearance. Optimum texture and color were achieved after defatting and decolorizing CGM with ethyl acetate. A juice extractor separated sugar beets into 68% sugar-containing juice, potentially useful in fermentation and for sugar production, and 32% pulp.

Projected Completion Date

N/A

Related Publications

Wu, Y.V., K.R. Sexson, and J.S. Wall. "Reverse osmosis of soluble fraction of corn stillage." Cereal Chem. 60:248-251. 1983.

Wall, J.S., R.J. Bothast, A.A. Lagoda, K.R. Sexson, and Y.V. Wu. "Effect of recycling distillers' solubles on alcohol and feed production from corn fermentation." J. Agric. Food Chem. 31:770-775. 1983.

Bookwalter, G.N., W.F. Kwolek, K.A. Warner, J.S. Wall, Y.V. Wu, and M.R. Gumbmann. "Investigations on the use of distillers' grains or fractions thereof in blended foods for The Foods for Peace Program and other food applications", Final Report to U.S. Congress, NRRC, Peoria, Illinois. 38 pp. 1983.

Neumann, P.E., C.E. Walker, and H.L. Wang. "The effects of fermentation with proteolytic fungi *Aspergillus oryzae* and *Rhizopus oligosporus* on the nutritional quality of corn gluten meal protein." *J. Food Sci.*, in press.

Title: Innovative Fermentation Technology for Alcohol Production

Performing Organization: Northern Agricultural Energy Center

Principal Investigator(s): Marvin O. Bagby, Rodney J. Bothast
USDA-Northern Regional Research Center
1815 N. University St.
Peoria, IL 61604 (309) 685-4011, ext. 531

Sponsoring Organization: USDA-ARS

Project Location: Peoria, Illinois

Project Summary

Studied innovative fermentation techniques such as continuous reactors with encapsulated microorganisms, and examined and screened organisms including yeasts, bacteria and molds for improved substrate and product tolerance, higher rates of fermentation, etc.

Project has been terminated.

Projected Completion Date

March 8, 1984

Related Publications

G.W. Nofsinger, J.E. Van Cauwenberge, R.J. Bothast, and W.F. Kwolek. "An evaluation of chemical methods to extend the allowable storage time of wet distillers' grains." J. Agric. Food Chem., 31(2):276-279. 1983.

Van Cauwenberge, J.E., A.A. Lagoda, R.J. Bothast, S.E. Allen, and G.C. Fahey, Jr. "Captan-treated seed corn in alcohol production." J. Agric. Food Chem., 32(1):75-78.

Silman, R.W. "Ethanol production by *Zymomonas mobilis* in fed-batch fermentations." Biotechnol. Bioeng., in press.

Title: Microbiological and Enzymatic Procedures for Conversion of Agricultural Residues and Biomass

Performing Organization: Northern Agricultural Energy Center

Principal Investigator(s): Marvin O. Bagby, Robert W. Detroy,
Rodney J. Bothast, and Merle E. Carr
USDA-Northern Regional Research Center
1815 N. University St.
Peoria, IL 61604 (309) 685-4011, ext. 531

Sponsoring Organization: USDA-ARS

Project Location: Peoria, Illinois

Project Summary

Hydropulping, dilute acid pulping, alkali extraction, alkali extraction after hydropulping, and alkaline hydrogen peroxide were evaluated for their effectiveness in removing pentosans and lignin from wheat straw and for increasing accessibility of the cellulose to enzymatic hydrolysis. Pentosans were removed preferentially and in greater yield by alkali. Dilute acid pulping provided 5-carbon sugars (mostly xylose) directly. Although all treatments increased cellulose accessibility, alkaline hydrogen peroxide removed lignin more completely and was the most effective. Cellulose was produced by 7 strains of _Spicellum roseum_ in both liquid and wheat bran solid substrate cultures. High yields (90%) of ethanol were produced continuously from both saccharified corn starch and commercial glucose for 10 days of an 18 day fermentation at 30°C with calcium alginate entraped _Saccaromyces cerevisiae_. _Candida wickerhamii_ encapsulated into calcium alginate beads (1 x 10^9 cells/bead) converted cellobiose to glucose continuously for 14 days; however, ethanol yield was only 50-80% basis glucose. _C. wickerhamii_ and _Saccharomyces cerevisiae_ encapsulated together increased ethanol production by 10%.

Projected Completion Date

N/A

Related Publications

Detroy, R.W., R.L. Cunningham, and A.I. Herman. "Fermentation of wheat straw hemicellulose to ethanol by _Pachysolen tannophilus_." _Biotechnol. Bioeng. Symp._ No. 12:81-89. 1982.

Cunningham, R.L., R.W. Detroy, and M.E. Carr. "Thermal hydropulping of wheat straw." _Trans. Ill. State Acad. Sci._ 75(3 and 4):283-287. 1982.

Detroy, R.W. and G. St. Julian. "Biomass conversion: Fermentation chemicals and fuels." _CRC Crit. Rev. Microbiol._, 10(3):203-228. 1983.

Fanta, G.F., T.P. Abbott, A.I. Herman, R.C. Burr, and W.M. Doane. "Hydrolysis of wheat straw hemicellulose with trifluoroacetic acid. Fermentation of xylose with *Pachysolen tannophilus*." *Biotechnol. Bioeng.*, in press.

Carlson, K.D., R.L. Cunningham, and A.I. Herman. "Sweet sorghum grown on sludge-amended stripmine soil: A preliminary look at yields, composition, and ethanol production." *Trans. Ill. State Acad. Sci.*, 76(3 and 4):111-122.

Silman, R.W., J.E. McGhee, and R.J. Bothast. "Cellulose production by *Spicellum roseum* in liquid and solid culture." *Biotechnol. Bioeng.*, in press.

Title: Curriculum Development and Training Facility for Alcohol Fuels Production

Performing Organization: Southeastern Illinois College

Principal Investigator(s): Stanley O. Jones
Southeastern Illinois College/Vienna Correctional Center
Vienna, IL 62995 (618) 658-4051

Sponsoring Organizations: U.S. Department of Energy, Illinois State Board of Education, Illinois Correctional Industries

Project Location: Vienna Correctional Center, Vienna, Illinois

Project Summary

Southeastern Illinois College at the Vienna Correctional Center is developing a 500,000 gallon per year alcohol fuels plant which will provide fuel-grade alcohol for vehicles operating on institutional grounds. Anhydrous alcohol, or ethanol, will also be produced for gasoline blends used in fleet vehicles operated by the State of Illinois. Byproducts such as distiller's grain, carbon dioxide and waste heat will be utilized by other institutional projects: cattle raised on institutional land will be fed distiller's grain, catfish farms will make use of the smaller particles of distiller's grain for feed and a greenhouse will function on the waste heat and CO_2 coming from the plant.

In addition to the fuel and byproducts produced at the alcohol plant, the plant will serve as an educational facility to train individuals in the operation of an industrial-type facility. Students enrolled in the alcohol fuels program will undergo a one-year certificate training program that will enable them, through various classes and on-the-job training, to operate an alcohol fuels production facility. In more general terms, the fuels production training received at Southeastern Illinois College--Vienna Correctional Center will allow students to become familiar with the many aspects of all industrial and agricultural operations. The first students to finish the training program will graduate in December 1983.

Projected Completion Date

Ongoing

Related Publications

Ethanol Production Technology

Title: Integrated Alcohol Fuel Production Facility

Performing Organization: Southeastern Illinois College at Vienna
Correctional Center

Principal Investigator: Mr. Stanley O. Jones
Alcohol Fuels Coordinator
Southeastern Illinois College at Vienna
Vienna Correctional Center
Vienna, IL 62995
(618) 658-9090

Sponsoring Organizations: Southeastern Illinois College
IL Department of Energy and Natural Resources
IL Department of Corrections

Project Location: Vienna Correctional Center
Vienna, Illinois

Project Description

Southeastern Illinois College is implementing a complete training facility for the production of ethanol for fuel located at the Vienna Correctional Center. A curriculum for teaching alcohol fuel production has been developed and approved by the Illinois Community College Board and the Board of Higher Education. A 500,000 gallon per year ethanol production plant has been constructed on the grounds of the Vienna Correctional Center to give students work experience in a cooperative sized plant. The plant will also be utilized as a resource for the development of new ways to utilize by-products that are now lost with no value in conventional systems.

Three major problem areas are being addressed by this project. The first problem area is the loss of valuable protein by the distiller's solubles. SIC proposes to incorporate the solubles into a feeding program for fresh water shrimp and golden shiners. Construction has been completed on five quarter-acre ponds and a 2 acre reservoir for the production of the fish. The applicability of using the solubles as feed for aquatic life will be tested under the supervision of SIU-C Department of Fisheries. The distiller's solubles will also be utilized as a source of nutrients in a hydroponic greenhouse to study their value for plant growth. The solubles will also be distributed on soil plots to test for benefits as a soil fertilizer.

The second problem area addressed is the utilization of the corn distiller's grains (CDG) in their wet form. Feeding trials will be run on feedlot steer to test their performance when utilizing the wet CDG as a source of feed protein. Various feed rations will be tested to determine the optimum mix. SIC will also research the use of the CDG as a feed for quail and pheasants.

The third problem area is the loss of CO_2, a by-product of alcohol production, to the atmosphere. CO_2 will be piped into a greenhouse for plant enrichment and also utilize the waste heat contained in the CO_2. SIC will test the waste heat recovery potential by passing it through a heat exchanger.

Funding was secured by Southeastern Illinois College from the Department of Energy, Department of Adult Vocational and Technical Education, Illinois Correctional Industries and CETA for the development of a 500,000 gallon per year alcohol fuels training plant.

The performance of the plant will be monitored by electrical, mechanical, and accounting systems: temperatures will be monitored by 24 thermocouples; product quality (proof) will be monitored by hydrometers and spectrometers; electronic pH meters will be used to monitor fermentation to detect unwanted bacterial growth. The data presented by the controls will be recorded and analyzed periodically.

Projected Completion Date

December 1984

Title: On-Farm Anaerobic Digester and Fuel Alcohol Plant

Performing Organization: Southern Illinois University at Edwardsville

Principal Investigator(s): Harlan H. Bengston
Dept. of Engineering and Technology
Southern Ill. Univ. at Edwardsville
Edwardsville, Illinois 62026 (618) 692-2500

Sponsoring Organizations: IL Department of Energy and Natural Resources
Southern Illinois University at Edwardsville
Knobeloch Enterprises, Inc.

Project Location: Herbert Knobeloch, Sr. farm, near Mascoutah, Illinois

Project Summary

This project is a joint venture involving personnel from Southern Illinois University and from the Herbert Knobeloch, Sr. family. An integrated energy system is being developed, involving anaerobic digestion of swine manure and fuel alcohol production from corn. The two processes will be linked together so that the biogas produced by anaerobic digestion can be used as fuel for the alcohol plant and waste hot water from the alcohol plant can be used to maintain the digester at its required temperature. This combination of the two processes eliminates some drawbacks of each of the individual processes such as the need for burning a fossil fuel in the alcohol plant, the need to burn part of the biogas produced to maintain the digester temperature and the difficulty in using the biogas at just the rate at which it is produced.

The major components of the alcohol plant are a 12-inch diameter sieve plate distillation column, a 4,000 gallon cooker-fermenter, various storage tanks and transfer pumps and a gas-fired boiler which is presently fueled with propane, but will be converted to biogas as soon as enough biogas is collected. A conical solid-bowl centrifuge is being constructed for solid-liquid separation from the mash. The system is designed to produce 180 to 190 proof alcohol.

The anaerobic digestion system is made up of several components. A hog finishing house, which already had a slotted floor and manure pit below it, was fitted with a system to scrape the manure into a slurry pit at one end of the hog house. A sewage pump feeds the manure daily from the slurry pit into the digester, a 13,000 gallon tank car body which has been insulated with styrofoam and buried underground. Another sewage pump is used to transfer effluent (digested manure) from the digester to a 150,000 gallon storage tank. The digested manure is then applied to cropland at appropriate times of the year. The digester temperature is maintained by automated hot water circulation through an internal heat exchanger made of 2-inch steel pipe. An 80 square foot, water-heating solar collector has been built to provide heat to the digester also. The biogas produced in the digester is pumped into a 32,000 gallon gas storage tank.

Projected Completion Date

December 31, 1984

Title: Polyculture of Freshwater Prawn (Macrobrachium rosenbergii) and Golden Shiner (Notemigonus crysoleucas) using Ethanol Distiller's By-products as a Food Source

Performing Organization: Southern Illinois University-Carbondale
Fisheries Research Laboratory

Principal Investigator(s): Christopher C. Kohler and William M. Lewis
Fisheries Research Laboratory
Southern Illinois University
Carbondale, IL 62901 (618) 453-2890

Sponsoring Organizations: U.S. Department of Energy (DE-FG02-81510295)
Southern Illinois University-Carbondale
Illinois Department of Corrections
(Correctional Industries)
Southeastern Illinois College-Vienna

Project Location: Vienna Correctional Center
Vienna, Illinois

Project Summary

Two major by-products of ethanol distillation, corn distiller's solubles and corn distiller's mash, were evaluated for their potential use as a food source for freshwater prawn (Macrobrachium rosenbergii) and golden shiner (Notemigonus crysoleucas) in the midwestern United States. Corn distiller's solubles were not found to be highly toxic to aquatic organisms at concentrations ranging up to 10,000 ppm. However, the high biological oxygen demand of the material requires that single applications not exceed 2,000 ppm. Yield trials were conducted over a four-month period in five 0.1 ha earthen ponds, located in proximity to an ethanol distillery. Each pond was stocked with 2,000 postlarval shrimp (0.2 g mean weight). Three of these ponds were also stocked with 75 adult golden shiner (27.0 g mean weight). One application of corn distiller's solubles (equivalent to 2000 ppm) and three applications of corn distiller's mash (5 kg/application) were made over the course of the yield trials (120 days). No other food or fertilizer was added to the ponds. Survival of shrimp ranged from 34 to 75 percent. Survival of brood fish exceed 90 percent. Mean weight of shrimp at harvest was approximately 12 g, and average production was equivalent to approximately 104 kg ha^{-1}. Golden shiner reared in the same ponds as shrimp had production rates equivalent to approximately 130 kg ha^{-1}. The presence of fish did not appear to impede shrimp production. Although production results of fish and shrimp were encouraging, several factors existed which impeded production; these included: 1) little by-product was applied to ponds because the distillery was undergoing its "shakedown" period; 2) ponds were new and had minimal natural productivity; 3) grass was not fully established on the watershed and ponds became turbid; and 4) lower than normal temperatures prevailed over much of the growing period. Accordingly, it is anticipated that production of fish and shrimp can be significantly increased in future trials, and that aquaculture may be a profitable means for utilizing the by-products of corn-ethanol distillation.

Projected Completion Date

Continuing study

Related Publications

Kohler, C.C., W.M. Lewis, and S.P. Krueger. "Preliminary observations on use of ethanol distiller's by-products for polyculture of freshwater prawn (*Macrobrachium rosenbergii*) and golden shiner (*Notemigonus crysoleucas*)." *First Biennial Conference on Warmwater Aquaculture-Crustacea*, Brigham Young University-Hawaii Campus, Laie, Hawaii, February 1983. In press.

Title: Regulation of Alcohol Fermentation by Escherichia coli

Performing Organization: Southern Illinois University
Department of Microbiology

Principal Investigator(s): David P. Clark
Department of Microbiology
Southern Illinois University
Carbondale, IL 62901 (618) 453-3737

Sponsoring Organization: U.S. Department of Energy

Project Location: Carbondale, Illinois

Project Summary

I intend to investigate how the production of alcohol by the bacterium *Escherichia coli* is regulated. *Escherichia coli* produces ethanol when fermenting sugars under anaerobic conditions. The pathway for ethanol production is repressed by oxygen and other electron acceptors and is also inoperative when conditions are too acid. New advances in genetics such as molecular cloning of the genes for enzymes involved in alcohol production and the isolation of gene fusions will be used. Mutants which lack alcohol dehydrogenase and those which overproduce this key enzyme will be used as a starting point for the genetic analysis. The gene for alcohol dehydrogenase has been located on a large restriction fragment on a bacteriophage vector. Future work will involve subcloning of small fragments into high copy-number vectors and a detailed analysis of the regulatory elements associated with this gene. Further investigations, of similar nature, will then be pursued for the second enzyme of the alcohol production pathway: acetaldehyde dehydrogenase. Understanding how alcohol production is regulated should allow the construction, by genetic engineering, of more efficient producer organisms.

Projected Completion Date

July 1985

Related Publications

Clark, D. and J.E. Cronan. "*Escherichia coli* mutants with altered control of alcohol dehydrogenase and nitrate reductase." *J. Bacteriol.* 141: 177-183, 1980.

Clark, D. and J.E. Cronan. "Acetaldehyde coenzyme A dehydrogenase of *Escherichia coli*." *J. Bacteriol*. 144: 179-184, 1980.

Lorowitz, W. and D. Clark. "*Escherichia coli* mutants with a temperature-sensitive alcohol dehydrogenase." *J. Bacteriol*. 152: 935-938, 1982.

Title: Use of Corn Distiller's Solubles from an Ethanol Plant for Aquaculture

Performing Organization: Southern Illinois University
Fisheries Research Laboratory

Principal Investigator(s): Christopher C. Kohler and
William M. Lewis
Fisheries Research Laboratory
Southern Illinois University
Carbondale, Illinois 62901 (618) 453-2890

Sponsoring Organizations: U.S. Department of Energy
Illinois Department of Corrections
Southern Illinois University-Carbondale
Southeastern Illinois College-Vienna

Project Location: Vienna Correctional Center
Vienna, Illinois

Project Summary

Gasohol (a mixture of gasoline and alcohol, usually ethanol) is increasingly being used in many states as a means to reduce our nation's dependence on imported oil. However, profitable uses for the by-products of the distillation process need to be identified if ethanol is to become a significant and economical alternative fuel supply. Wet corn distiller's grains have shown potential as a feed supplement for cattle. However, the soluble fraction (with suspended particles) is of little food value to terrestrial animals because of its high water content, and it is not economically feasible to concentrate it further. We are currently investigating the use of the by-product as a food source in an aquatic environment where its high water content does not necessarily pose an impediment. Many aquatic organisms are capable of utilizing as a food suspended materials in the water column. Primarily among these are microcrustaceans, minute animals that are at times a major source of food for nearly all fish species. Furthermore, those fishes which are planktophagus (feed on plankton) are also capable of directly assimilating particulates from the water column. This report describes results of initial laboratory studies which have focused on assessing the short-term effects of various concentrations of corn distiller's solubles on water quality and aquatic organisms (fish, macrocrustaceans, microcrustaceans and algae).

Methods

Fresh samples of corn distiller's solubles were obtained as a by-product of laboratory distillation of ethanol using crushed corn, dehydrated yeast and commercial enzyme mixtures. Golden shiner (*Notemigonus crysoleucas*) and crayfish (*Procambarus* sp.) were used as test fish and test macrocrustacea, respectively. Twelve 110-liter aquaria were used in the assessment of toxicity of corn distiller's solubles on the test organisms. Corn distiller's solubles were applied in replicated treatments at rates of 0, 1,000, 1,800, 3,200, 5,600 or 10,000 ppm. Survival of test organisms was recorded over a 96-hour period for determination of a 96-hr LC_{50} (lethal concentration where

50 percent of test organisms survive over a 96-hour period). Two identical bioassays were conducted.

A culture of Daphnia was maintained in a 110-liter aquarium. However, 300 ml Erlemyer flasks were used as experimental units for conducting a 96-hour LC_{50}. Flasks were filled with 200 ml of reconstituted freshwater. Three identical bioassays were conducted in which flasks were treated with corn distiller's solubles at rates equivalent to 0, 1,000, 1,800, 3,200, 5,600 or 10,000 ppm. One hour following by-product application, 10 Daphnia were stocked in each flask. Survival was recorded over a 96-hour period for determination of a 96-hour LC_{50}.

Effects of corn distiller's solubles on a representative alga were assessed by comparing O_2 levels in experimental units receiving various concentrations of the by-product. Tests were conducted by placing a 200 ml homogeneous sample of Chlamydomonas in each of six 300 ml Erlemyer flasks. Flasks were then supplied with corn distiller's solubles at rates equivalent to 0, 1,000, 1,800, 3,200, 5,600 or 10,000 ppm. Treatments were maintained under an alternating photic schedule of 15 hours of light and 9 hours of darkness for a 96-hour period. Dissolved oxygen and pH measurements were obtained prior to application of the by-product and after each subsequent 15-hour light period.

Results

Corn distiller's solubles were apparently not acutely toxic to fish or crayfish at concentrations up to 10,000 ppm. Only one mortality occurred among each test group during the two separate 96-hour test periods. Both deaths were apparently due to crayfish predation/cannibalism.

Acute toxicity tests indicated that corn distiller's solubles may be toxic to Daphnia. A 96-hour LC_{50} was estimated at 2,271 ppm, and the upper and lower 95 percent confidence values were 1,859 ppm and 2,762 ppm, respectively.

Dissolved oxygen declined precipitously in the algal cultures following application of the corn distiller's solubles. However, alkalinity, hardness, nitrates, ammonia and pH were not significantly altered by the addition of the ethanol by-product.

It is noteworthy that golden shiners were observed to actively consume the particulates of the corn distiller's solubles. Following the bioassays, stomach contents of several shiners were analyzed which confirmed our visual observations. Direct consumption of the particulates by fish makes the use of corn distiller's solubles in aquaculture much more attractive than if the byproduct only serves to increase pond fertility.

Field studies are currently being conducted using earthen ponds in proximity to an ethanol distillery of the Vienna Correctional Center. The distillery is a cooperative venture of the Illinois Department of Corrections (Prison Industries) and the Vocational Training Program of Southeastern Illinois College-Vienna.

Projected Completion Date

Continuing study

Related Publications

In preparation

Title: The Use of Ethanol Distillery By-Products in Aquaculture

Performing Organization:	Southern Illinois University Carbondale Fisheries Research Laboratory
Principal Investigator:	Dr. Christopher Kohler SIU-C Fisheries Research Laboratory SIU-Carbondale Carbondale, IL 62901
Sponsoring Organizations:	IL Department of Energy and Natural Resources Southern Illinois University - Carbondale
Project Location:	Vienna Correctional Center Vienna, Illinois

Project Description

SIU Fisheries Research Laboratory will evaluate the use of two ethanol distillation by-products (corn distiller's solubles and corn distiller's grains) as a food for rearing fish. The ethanol plant that will supply the by-products is located at the Vienna Correctional Center, a minimum security prison near Vienna, Illinois. The fish will be raised in five 1/4 acre ponds located on the correctional center's grounds. The ponds have been constructed specifically so that SIU-Carbondale can conduct aquaculture research using the by-products of ethanol distillation as a fish feed.

The study consists of laboratory studies and field trials. There are four major objectives to this project. Objective number one is to identify if and how planktophagus fish utilize corn distiller's solubles as a source of food. The golden shiner will be used as the test organism (Planktophagus fish) since much is known about the fish and it has been the subject of considerable published research. Lab trials will be conducted to see if the shiners can directly utilize the corn distiller's solubles as food. The by-product may prove to be a suitable medium for microcrustaceans, which in turn would represent a major source of food for the fish.

Objective number two is to determine the effects of daily applications of corn distiller's solubles (CDS) on water quality, micro-organisms, and planktophagus fish. As a preliminary study, major water quality parameters (e.g., dissolved oxygen, pH, CO_2, alkalinity, hardness) will be monitored over a 30-day period in 20-gallon aquaria individally treated with daily applications of CDS ranging from 0 to 10,000 ppm. Two aquaria will be used for each application rate. Using this preliminary study as a guideline, several application rates of CDS will be evaluated as a medium for production microcrustaceans and algae (Daphne and Chlorella species). Two aquaria will be used for each control and treatment. Using the above results, the effect of daily applications of CDS on the golden shiner will be evaluated over a 1- to 4-month period. Controls and replications will be used and the water quality will be monitored.

Objective number three is to assess the use of corn distiller's solubles (CDS) for pond culture of planktophagus fish. One control pond will be stocked with golden shiners and will receive no CDS applications. Three more ponds will be stocked with golden shiners and will receive daily applications of CDS. The daily CDS application rates will be selected based on the lab findings. The yield trial will be conducted for approximately four months. Microcrustaceans and micro-algae populations will be monitored, both qualitatively and quantitatively during the course of the yield trial. Fish will be sampled regularly for food habit analysis. Major waste quality parameters and growth and conditions of the fish will also be monitored.

Objective number four is to determine the potential for using corn distiller's grains (CDG) as a component of a moist fish feed. The CDG will be combined with various foodstuffs for the purpose of developing an inexpensive, moist fish feed. Based on lab findings, the experimental feed showing the most promise will be evaluated in pond culture yield trials using channel catfish (non-planktophagus).

At the end of the yield trials the ponds will be rapidly drained and the fish collected in a catchment basis and analyzed. The data will be analyzed statistically by use of computers and the results will be summarized using table and graphical displays.

Projected Completion Date:

December 1984

Title: Butanol Production by Fermentation of Extruded Corn

Performing Organization:	Dept. of Agricultural Engineering and Food Science University of Illinois at Urbana-Champaign
Principle Investigator(s):	Dr. H.P. Blaschek Department of Food Science University of Illinois 905 South Goodwin Avenue Urbana, Illinois 61801 (217) 333-8224
Sponsoring Organizations:	Illinois Department of Energy and Natural Resources Springfield, Illinois Agricultural Experiment Station College of Agriculture University of Illinois at Urbana-Champaign Research Board University of Illinois at Urbana-Champaign
Project Location:	Urbana, Illinois

Project Summary

The overall objective of the microbiological portion of this project is to develop a strain of C. acetobutylicum that demonstrates an increased conversion of corn starch to butanol at a higher concentration of butanol in the fermentation broth.

The following accomplishments have been made:

1. By employing serial enrichment, a mutant of Clostridium acetobutylicum ATCC 824 was obtained which grew at concentration of butanol that prevented growth of the wild-type strain. It was designated SA-1. The SA-1 mutant demonstrated a 121 percent increase in butanol tolerance and a 13.2 percent improvement in the ability to produce butanol over the wild-type strain in 6 percent extruded corn broth.

2. Characterization of the wild-type and SA-1 strain in 6 percent extruded corn broth demonstrated the following:

   a. SA-1 produced consistently higher concentrations of butanol (5 to 14 percent) and lower concentrations of acetone (12.5 to 40 percent) than the wild-type strain in 4 to 20 percent extruded corn broth. The best solvent ratio with respect to optimizing butanol and decreasing acetone occurred between 4 and 8 percent extruded corn broth for SA-1.

   b. SA-1 demonstrated higher conversion efficiency of extruded corn to butanol than the wild-type strain at every concentration of extruded corn broth tested.

   c. SA-1 was superior in terms of growth rate (doubling time: 32.8 min versus 57.9 min for wild-type strain), time of onset of butanol production (6-12 h earlier), carbohydrate utilization, pH resistance and final butanol concentration in the fermentation broth.

3. Development of systems for genetic manipulation of C.acetobutylicum:

   a. We have been successful in the development of an efficient plasmidgene transfer system for C.acetobutylicum SA-1 based on transformation of heated protoplasts.

   b. We have successfully shotgun-cloned chromosomal DNA from C.acetobutylicum SA-1 into Bacillus subtilis 1A289 using plasmid pUB110 as vector.

Currently, we are attempting to shotgun-clone the a-amylase gene from hyperproducing strains of Bacillus into the C. acetobutylicum SA-1 butanol-tolerant mutant in order to further elevate the corn to butanol conversion efficiency at a high concentration of butanol in the fermentation broth.

Projected Completion Date

December 1985

Related Publications

Lin, Y.L. and H.P. Blaschek. "Butanol production by a butanol-tolerant strain of Clostridium acetobutylicum in extruded corn broth." Abstract No. 013, Annual Meeting of the American Society for Microbiology, New Orleans, LA, March 6-11, 1983.

Lin, Y.L. and H.P. Blaschek. "Butanol production by a butanol-tolerant strain of Clostridium acetobutylicum in extruded corn broth." Appl. Environ. Microbiol. 45: 966-973, 1983.

Lin, Y.L. and H.P. Blaschek. Transformation of heated Clostridium acetobutylicum protoplasts with pUB110 plasmid DNA. Abstract No. H79, Annual Meeting of the American Society for Microbiology, New Orleans, LA, March 6-11, 1983.

Lin, Y.L. and H.P. Blaschek. Transformation of heated Clostridium acetobutylicum protoplasts with pUB110 plasmid DNA. (Submitted for publication.)

Title: Hydrogen and Protein by Electrochemical Oxygenation of Biomass

Performing Organization: Agricultural Engineering Department
Illinois Agricultural Experiment Station
University of Illinois At Urbana-Champaign

Principal Investigator(s): T. J. Brumm, D. L. Day, M. P. Steinberg
Agricultural Engineering Department
University of Illinois
1208 W. Peabody Dr.
Urbana, IL 61801 (217) 333-2693

Sponsoring Organization: U.S. Department of Agriculture, Illinois
Agricultural Experiment Station

Project Location: Agricultural Engineering Department,
University of Illinois

Project Summary

This study examines in situ electrolysis of water for oxygenating aerobic fermentations as an alternative to mechanical aeration. The nitrogen in biomass such as liquid manure is upgraded to single-cell protein and hydrogen is a byproduct.

A 10 L reactor with the appropriate electronic controls was built to explore the premise that redox could be an effective control parameter to turn on and off the electrical supply for optimum electrolysis. The reactor was willed with swine manure (1 percent GS) and a 10 percent inoculum of oxidation ditch mixed liquor (ODML) from an operating aerobic process. The control equipment was set to a desired level of -200 mV and a potential of 3 volts was impressed on the electrode (parallel) stack of the electrochemical cell. After a few weeks, when a favorable ORP level was reached with the corresponding physical evidence of aerobicity (brownish color with low odor), substrate feeding started at a very low rate (approx. a 90-day detention time). The system proved to be unstable, as evidenced by a rapid drop in ORP (within 24 hours). Typical ORP levels of -400 mV were seen through most of the experiment's duration of approximately 6 weeks. Possible causes of failure were thought to be that the reactor design allowed inadequate mixing, hence solids settling and the resultant anaerobic pockets affected the ORP of the liquor, and that the anode surface to reactor volume ratio may have been too low, resulting in an inadequate amount of anode area for microbial respiration.

With these problems in mind, a new reactor was designed to provide for adequate mixing, provide a larger amount of anode area and give a flow pattern that forced the entire liquid contents of the reactor through the electrode stack. Calculations of expected oxygen production versus oxygen demand indicated there would be adequate oxygenation.

Events similar to the first attempt at redox control occurred. With only inoculum and no substrate feeding, ORP levels reached a satisfactory level. It was, however, very unstable. When substrate was added even in small quantities, the ORP level dropped. It was evident that redox could not be the control variable needed.

One possible explanation is that the presence of hydrogen depresses the ORP levels in the reactor. To test this hypothesis, an experiment was performed wherein ORP levels were measured in a liter of anaerobic digester effluent (-450 mV) which was alternately sparged with air, hydrogen and nitrogen. Air sparging (at approximately 100 cc/min) resulted in an ORP of -50 mV in 30 minutes. Bubbling hydrogen at a similar rate caused the reading to drop percipitously to -700 mV in 15 minutes. Nitrogen was used to "flush" the hydrogen from the liquor, but this took a longer time to raise ORP levels than did air. It was concluded that the presence of hydrogen from electrolysis suppressed ORP levels (either physically or artificially), therefore, this parameter did not reflect the activity of the microflora as expected and could not be used to control the electrochemical process.

Projected Completion Date

August 1984

Related Publications

Kravets, R.R., D.L. Zierath, M.P. Steinberg and D.L. Day. "Electrochemical conversion of liquid manure into protein and hydrogen." Proc., Fourth Int. Symposium on Livestock Wastes, American Soc. Agricultural Engineering, St. Joseph, Michigan, 1981, pp. 27-30.

Brumm, T.J., M.P. Steinberg and D.L. Day. "Electrochemical oxygenation of livestock wastes." Biotechnology and Bioengineering Symp. No. 12. John Wiley and Sons Inc. CCC0572-6565101327. 1982. pp. 327-335.

Brumm, T.J., D.L. Day and M.P. Steinberg. "Electrochemical fermentation of biomass." Paper No. 83-3573, American Society of Agricultural Engineers, presented at Chicago, IL, December 1983.

Title: A Biogas Plant for an Integrated Biomass Energy System for Illinois Agriculture

Performing Organization: Illinois Agricultural Experiment Station
Department of Agricultural Engineering
University of Illinois At Urbana-Champaign

Principal Investigator(s): D.L. Day and C.B. Fedler
Dept. of Agricultural Engineering
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Urbana, Illinois 61801 (217) 333-2693

Sponsoring Organizations: Illinois Department of Energy and Natural Resources
Springfield, Illinois

Agricultural Experiment Station
College of Agriculture
University of Illinois at Urbana-Champaign

Office of Energy Research/USDOE
University of Illinois at Urbana-Champaign

Project Location: Urbana, Illinois

Project Summary

The University of Illinois anaerobic digester on the new swine research farm is a component of an integrated farm energy system. The farm has a capacity equivalent of a farrow-to-finish unit marketing 3,000 pigs per year. The swine facility supplying the digester is a totally enclosed, modern confinement unit with partially slotted floors. The manure produced from the animals in some of the buildings is scraped from under the slats several times each day to a central sump before being pumped to the anaerobic digester.

This system is being built to provide the University of Illinois College of Agriculture with an operational biogas production unit, as well as with a research unit that can be used to demonstrate the technology of methane generation and utilization. Since the unit is readily accessible, it will also provide a unique opportunity for demonstrating the concept of methane generation from biomass to students, agricultural extension workers, consultants, and farmers who participate in the College's education program.

The main tank of the anaerobic digester unit is composed of four compartments: a gas storage unit, a gas processing unit, a reactor, and a sludge storage unit (see Figure 1). The four connected compartments are cylindrical in shape and are divided by 12-inch-thick concrete walls. The total unit is laid horizontally in the ground. A separate tank is also provided for mixing, processing, and preheating the incoming manure. The tanks were fabricated on-site from rolled 0.040-inch-thick galvanized steel. The interiors and exteriors of the tanks were insulated with spray-on polyurethane and then sealed on the inside with a spray-on rubber lining. The remainder of the unit not buried in the ground was mounded over with earth to provide additional insulation.

There was a dedication and open-house of the project "An Integrated Biomass Energy System for Illinois Agriculture" October 28, 1983.

Projected Completion Date

June, 1984

Related Publications

Fedler, C.B. The anaerobic digester on the swine research farm at the University of Illinois. Proc., Livestock Waste Management Conf., Agri. Engr. Dept., Univ. of Ill. at Urbana-Champaign. 1983. pp. 42-47.

Chew, T.H. "Kinetic parameters of themophilic digestion of swine manure." Paper No. 83-4059, American Society of Agricultural Engineers, presented at Bozeman, MT, June 1983.

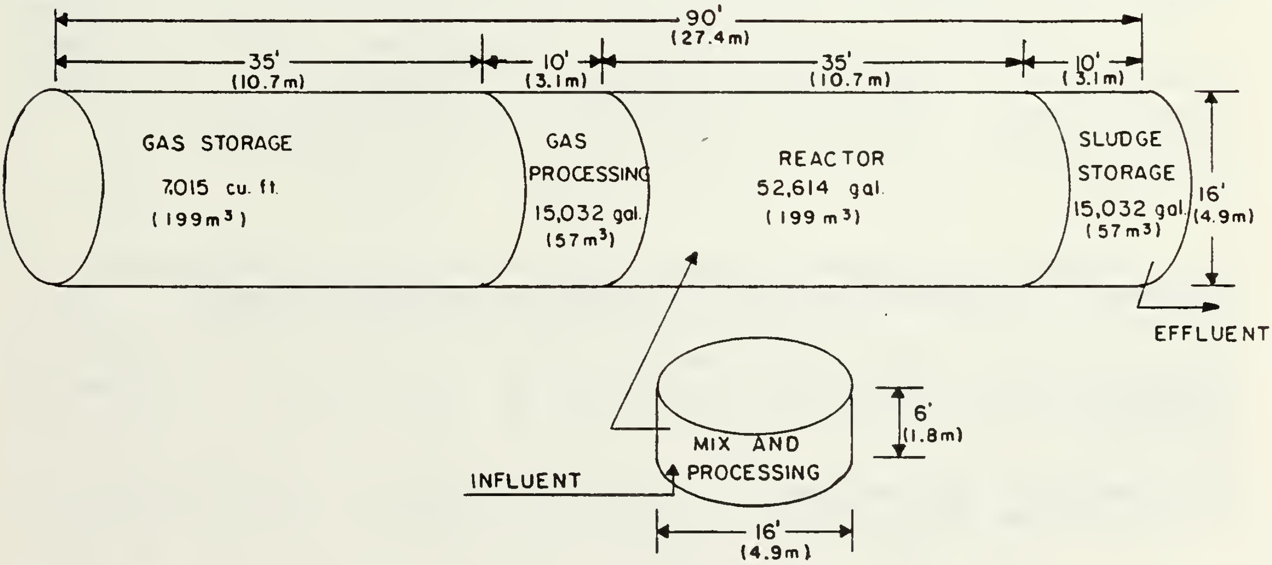

Figure 1. The anaerobic digester at the Swine Research Farm at the University of Illinois (constructed by Energy Resource Systems, Dewey, Illinois).

Title: An Integrated Biomass Energy System for Illinois Agriculture

Performing Organization: Dept. of Agricultural Engineering
University of Illinois At Urbana-Champaign

Principal Investigator(s): E.D. Rodda, D.L. Day, M.P. Steinberg
and D.R. Hunt
Dept. of Agricultural Engineering
University of Illinois
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Urbana, Illinois 61801 (217) 333-6762

Sponsoring Organizations: Illinois Department of Energy and Natural Resources
Springfield, Illinois

Agricultural Experiment Station
College of Agriculture
University of Illinois at Urbana-Champaign

Office of Energy Research/USDOE
University of Illinois at Urbana-Champaign

Project Location: Urbana, Illinois

Project Summary

An integrated biomass energy system for Midwest agriculture can be illustrated with the following example. With reference to Figure 1, assume a farm with 162 hectares (400 ac) of corn that produces 9 m^3/ha (120 bu/ac). It would require 54,380 l (14,360 gal.) of 160-proof alcohol for use in a tractor, combine, and truck to accomplish the farming operations.

The corn produced is: 120 bu/ac x 400 ac = 48,000 bu.

The amount of 160-proof alcohol required as fuel to produce the corn crop is: 35.9 gal/ac x 400 ac = 14,360 gal of 160-proof alcohol.

Assume the alcohol plant produces the equivalent of 2.4 gal/bu of 200-proof as 160-proof alcohol. This will be: 2.4 x 200/160 = 3 gal/bu of 160-proof.

Amount of corn required is: 14,360 gal ÷ 3 gal/bu = 4,790 bu corn. This is 10% of the corn crop.

Assume the alcohol plant runs 24 hr/day for 300 days/yr. Then capacity of the alcohol plant is:

$$\frac{14{,}360 \text{ gal}}{300 \text{ days}} \times \frac{\text{day}}{24 \text{ hr}} = 1.99 \text{ gal/hr.},$$

say 2 gal/hr of 160-proof.

Process heat required to operate the alcohol plant is:

$$\frac{26{,}120 \text{ Btu}}{\text{gal of 160-proof}} \times \frac{14{,}360 \text{ gal}}{\text{yr}} = 520 \times 10^6 \text{ Btu/yr}$$

To operate 300 days/yr, this is 1.73 of 10^6 Btu/day or 72,000 Btu/hr.

There will be a by-product of surplus whole stillage, assuming 50% stillage set back for succeeding fermentations, of 14 gal/bu at 88% moisture content, wet basis.

Surplus stillage for our example farm will be:

$$\frac{14 \text{ gal}}{\text{bu}} \times \frac{4{,}790 \text{ bu}}{\text{yr}} = 67{,}060 \text{ gal/yr.}$$

This will be 224 gal/day for the 300 day/year operation.

To supply supplemental protein in beef cattle rations, the cattle can utilize whole stillage at the rate of about 10 gal/hd-day (Berger, 1980). This would require:

$$\frac{224 \text{ gal}}{\text{day}} \times \frac{\text{hd-day}}{10 \text{ gal}} = 22 \text{ animals.}$$

However, at 5,342.8 kcal/m^3 (600 Btu/cu. ft.) of biogas, a total of 865,000 cu. ft. of biogas or 2,880 cu. ft./day will be needed. The number of beef cattle required to produce enough manure for the biogas is:

$$\frac{1.73 \times 10^6}{\text{day}} \text{ Btu} \times \frac{\text{hd-day}}{11{,}443 \text{ Btu}} = 150 \text{ animals.}$$

This is considerably more animals than the 22 needed to consume the stillage.

Sludge from the biogas plant that utilizes manure from 150 feedlot beef cattle at 364 kg (800 lb) average weight for 300 days/yr will have annual fertilizer values of 5,129 kg (11,284 lb) nitrogen (N), 1,969 kg (4,331 lb) phosphorus (P) and 4,303 kg (9,466 lb) potassium (K). This assumes no losses of fertilizer in the digester and normal losses due to handling and storage thereafter. Based on needing 166 kg/ha (148 lb/ac) of N 32 kg/ha (29 lb/ac) of P and 160 kg/ha (142 lb/ac) of K for an annual corn yield of 9.01 m^3/ha (120 bu/ac), the sludge can be used to fertilize 30 (76), 62 (154) or 27 hectares (66 acres), respectively, depending upon the decision to satisfy nitrogen, potassium or phosphorous requirements of the corn crop.

There are various alternatives for the system. For instance, many feedlot operators prefer to feed only stillage solids from a liquids/solids separator instead of whole stillage. If only stillage solids go to the feedlot, the thin stillage (raw wastewater) can go to the biogas plant to help produce process fuel for alcohol production, thus reducing the number of livestock needed.

A conservative estimate of methane production from thin stillage is 0.5 1 CH_4/g VS added. This is about 1,200 Btu/gal of thin stillage fed into he digester.

The energy content of biogas from thin stillage would be:

$$\frac{1200\text{ Btu}}{\text{gal}} \times \frac{200\text{ gal}}{\text{day}} = \frac{240{,}000\text{ Btu}}{\text{day}}$$

This is 14% of that required to operate the alcohol plant. Thus, the number of animals could be reduced by this amount or more if there were less than 50% set back of the stillage.

Research is continuing with the alcohol plant, the anaerobic digester, and the tractor that was converted to use alcohol instead of diesel.

Project Completion Date

June, 1984

Related Publications

Chen, T.H. "Kinetic parameters of thermophilic digestion of swine manure." Paper No. 83-4059, Amer. Soc. Agr. Engr., presented at Bozeman, MT, June, 1983.

Day, D.L. "Farm digesters for production of biogas -- literature review." Proceedings ROC-USA Workshop on Renewable Energy, Taipei, Taiwan, 1982. pp. 13-29.

Day, D.L., M.P. Steinberg and E.D. Rodda. 1984. "Integrated alcohol-methane systems for Midwest farms." Proc., Symp. on Energy from Biomass and Water, Lake Bueno Vista, FL, January 30 - February 3. Symp. Sponsored by the Institue of Gas Technology, Chicago, IL. (In press).

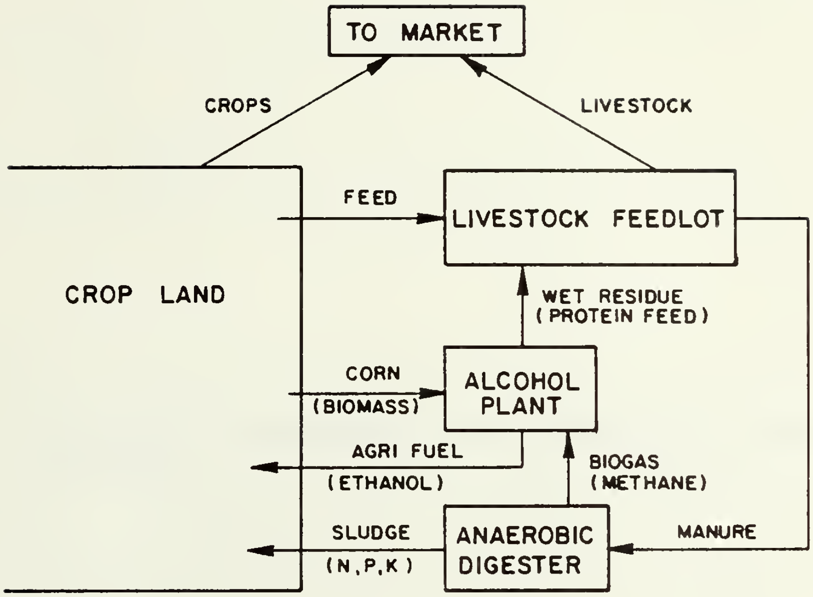
Fedler, C.B. "The anaerobic digester on the swine research farm at the University of Illinois." Proc., Livestock Waste Management Conf., Agri. Engr. Dept., University of Illinois at Urbana-Champaign. 1983. pp. 42-47.

Hunt, D.R. "Converting a diesel engine to alcohol." Agricultural Engineering, 61(12):12-13. 1980.

Hunt, D.R. "Alcohol for tractors-basic problems." Proc. Regional Workshops on Alcohol and Vegetable Oil as Alternative Fuels. SEA-Ext., USDA. Presented at Raleigh, North Dakota, April 7-9; Sacramento, California, April 21-23; and Peoria, Illinois, April 28-30.

Rodda, E.D. and M.P. Steinberg. "Energy analysis of an agricultural alcohol fuel system." Proc., Third International Conference on Energy Use Management, Berlin, October, 1981. pp. 1807-1814.

Steinberg, M.P., I. Bilgory and E.D. Rodda. "Triple effect distillation of beer containing particulates." Paper No. 83-3569, Amer. Soc. of Agr. Engr., presented at Chicago, IL, December 16, 1983.



INTEGRATED FARM FUEL SYSTEM

Figure 1. Flow scheme of the proposed integrated farm fuel system.

BIOENERGY: ALTERNATIVE FUEL PROPERTIES AND USAGE

Title: Physical/Chemical Modification of Vegetable Oils for Diesel Fuel

Performing Organization: Northern Agricultural Energy Center

Principal Investigator(s): Marvin O. Bagby, Everett H. Pryde
USDA-Northern Regional Research Center
1815 N. University St.
Peoria, Illinois 61604 (309) 685-4011, ext. 531

Sponsoring Organization: USDA-ARS

Project Location: Peoria, Illinois

Project Summary

Aqueous ethanol/vegetable oil microemulsions developed at the Northern Center have been studied in engine tests at the University of Illinois for heat release data and the 200-hour Engine Manufacturer's Association (EMA) screening test and at the Allis-Chalmers' Harvey, Illinois, plant under the supervision of North Dakota State University scientists for the EMA screening test. The heat release data indicate substantially greater amounts of premix combustion and lesser amounts of flame diffusion combustion for overall faster and smoother burning compared to No. 2 diesel oil. In the 200-hour EMA tests, microemulsions containing more than 50% vegetable oil maintained power output for the duration of the test, and in this aspect they gave results superior to those obtained with 25/75 blends of sunflower oil in diesel oil. However, carbon buildup and gummy deposits in the cylinders and buildup of polymerized vegetable oil in the lubricating oil indicated potential engine failure if the screening test had been continued beyond the prescribed time. Similar problems arose with a methanol/vegetable oil microemulsion that was developed at the Northern Center and tested at the University of Illinois. These problems can be ascribed to incomplete combustion in the engine, and further work is needed to determine the effects of additives to improve combustion efficiency as well as to improve removal of carbon deposits. Simple esters of vegetable oils continue to show most promise as alternative fuels, and all have passed the EMA screening tests.

Projected Completion Date

N/A

Related Publications

Pryde, E.H. "Vegetable oil as diesel fuels: Overview." *J. Am. Oil Chem. Soc.* 60:1557-1558. 1983.

Pryde, E.H. "Chemicals and fuels from commercial oilseed crops." *Fuels and Chemicals from Oilseeds: Technology and Policy Options*, eds., E.B. Schultz, Jr., and R.P. Morgan. AAAS/Westview Press, in press.

Pryde, E.H., and A.W. Schwab. "Cooperative work on engine evaluation of hybrid fuels." *Proc. Vegetable Oil as Diesel Fuel, Seminar III*, Northern Agricultural Energy Center, Peoria, Illinois. ARM-NC-28, pp. 90-95. 1983.

Schwab, A.W., and E.H. Pryde. "Vegetable oil methanol systems as fuels for diesel engines." *Proc. Vegetable Oil as Diesel Fuel, Seminar III*, Northern Agricultural Energy Center, Peoria, Illinois, 1983. ARM-NC-28, pp. 85-89. 1983.

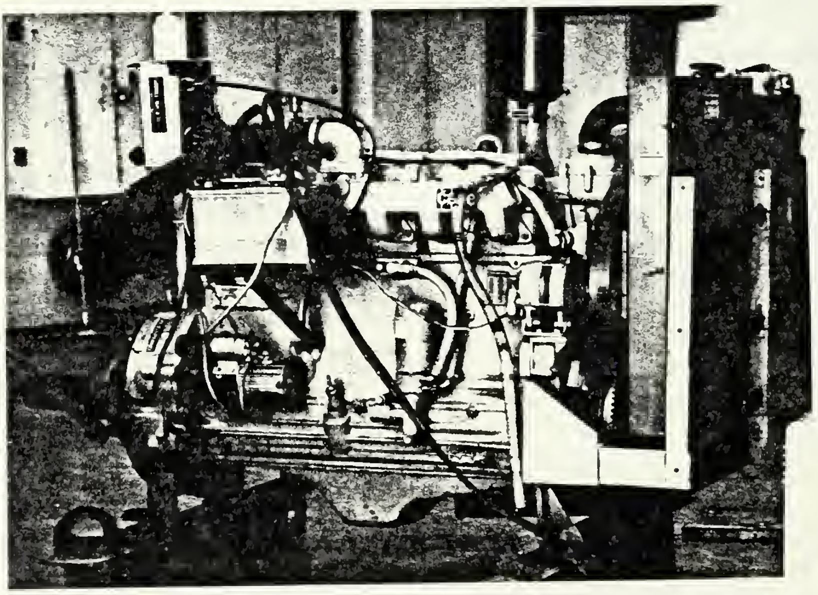
Bagby, M.O. "Seminar reflections and future research needs." *Proc. Vegetable Oil as Diesel Fuel, Seminar III*, Northern Agricultural Energy Center, Peoria, Illinois. ARM-NC-28, pp. 171-176. 1983.

Title: Alcohol Engine Conversion Project

Performing Organization:	Southeastern Illinois College
Principal Investigator(s):	Brittain A. Blair Southeastern Illinois College Harrisburg, Illinois 62946 (618) 252-6376
Sponsoring Organizations:	Southeastern Illinois College Illinois Department of Adult, Vocational and Technical Education
Project Location:	Harrisburg, Illinois

Project Summary

For the past three years, Southeastern Illinois College has been devoted to the technological and academic development of a renewable fuels program concerned with fuel alcohol production at its Vienna Correctional Center campus and engine conversion at its Harrisburg campus. With funds provided by the Illinois Department of Adult, Vocational and Technical Education (DAVTE) and the help of Dr. Richard F. Blaser, former technical consultant on alcohol engine conversion to the U.S. Department of Energy, Southeastern began, in 1979, the painstaking task of retrofitting spark ignition and diesel engines to burn high-proof alcohol. Since then, research efforts at the college have proved quite fruitful, and present conversion experimentation continues to yield encouraging results.



Using Dr. Blaser's BETA Theory, which focuses on combustion chamber redesign to allow maximum combustion efficiency, conversion technicians at Southeastern have successfully converted a 504 Case diesel to a multifuel engine capable of burning diesel fuel, alcohol fuel, kerosene and vegetable oil. Likewise, a gasoline-powered 301 Pontiac has been converted according to Blaser's BETA multifuel conversion principles. Using a somewhat different approach, Southeastern's technicians drew upon their own resources and the existing scholarship on alcohol engine conversion to develop and apply a series of carburetion, compression and ignition changes to convert three Chevrolet pickup trucks to burn high-proof alcohol. These trucks are now performing under actual road conditions with extraordinary success in all phases of operation.

Presently, extensive research is underway at Southeastern involving three new approaches in alcohol engine conversion. In one, Dr. Blaser is investigating the viability of a fueling system (injectors, pumps, etc.) in the form of a retrofitting kit designed to supply alternative motor fuels to spark ignition and diesel engines. Blaser says that the "fueling system is designed to supply a totally vaporized fuel to the combustion chamber in a stratified charge configuration. It will permit the utilization of various kinds of fuels, including gasoline, ethanol, methanol, other alcohols and diesel fuel, with just a minor adjustment to the fuel metering screw in the fueling device."

Dr. Blaser states that his fueling system arrangement is the simplest functional interaction of off-the-shelf hardware required for achieving the fundamental and unique improvement of fueling systems for internal combustion engines. The independent handling of the two reactants, fuel and air, to the working chamber of the internal combustion engine benefits from the contributions of the fuel device. The required fuel is then flash-evaporated for its direct supply to the working chamber during the intake event.

A second approach involves a multifuel carburetor designed to accommodate both petroleum and alcohol based fuels. Dr. Blaser is currently working with the drafting, machining and automotive departments at the Vienna Correctional Center to sophisticate and test the multifuel carburetor. The carburetor will come in the form of a retrofitting kit requiring only simple installation and maintenance.

Finally, Southeastern's own alcohol conversion technicians are continuing their experimentation with high compression, hoping to eventually combine the results of their research with Blaser's to produce an even more efficient and economical alcohol-burning engine. The first changes that are made to a spark ignition engine undergoing high compression alcohol conversion involve the engine's carburetor: the level of fuel in the fuel bowl must be raised and minor circuitry reproportioning must be preformed. Also, to help alleviate the problem of poor vaporization when starting the alcohol engine in cold weather, conversion technicians suggest installing a fuel preheater. Second, standard-compression-ratio pistons are replaced with 12.5:0 high-compression ratio-pistons. And finally, the ignition system of the engine is modified by advancing the timing of the distributor and installing hotter spark plugs with wider gaps.

Dr. Blaser, acting as coordinator for all three research activities, is currently pre-establishing scientific research through written documentation. Blaser's records will act as a foundation from which an alcohol engine conversion curriculum can be built.

Project Completion Date

N/A

Related Publications

Internal combustion engines for alcohol motor fuels: a compilation of background technical information

A competency based curriculum guide: ethanol spark ignition engine conversion

Illustrations for a competency based curriculum guide: ethanol spark ignition engine conversion

A curriculum guide for ethanol production technology

Title: Feasibility Study of Pulverized Forage as Diesel Fuel

Performing Organization: Sporting Goods Research

Principal Investigator:
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(217) 367-3397

Sponsoring Organizations:
Midwest Appropriate Technology
Small Grants Program
Contract #DE-FG02-81R510290
U. S. Department of Energy

Project Location: Urbana, Illinois

Project Description

This feasibility study was inspired by the frequent explosions of forage dust in grain elevators, where the conditions are far from ideal for combustion. In contrast, a diesel engine cylinder offers near perfect environment for burning powdered forage.

The energy content of most dried forage was found to average 8,000 Btu/lb. and the bulk density 16 to 20 lbs. per cu. ft. One cubic foot is equivalent to one gallon of #2 oil, or 133,250 Btu.

Pulverization of forage is necessary only to promote rapid combustion. Slow speed engines may use coarser particles at less cost for griding.

Pulverization of coal, however, is necessary both for combustion and to prevent abraision from entrained slag and rock, yet it is not a satisfactory fuel for turbines or internal combustion engines.

Powdered forage has no slag or entrained rock and only one-fifth of the E.P.A. allowable sulphur, thus it avoids the slag and pollution problmes.

Cost of processing and harvesting forage was estimated at $71.00 per ton or half the cost of #2 oil at $1.25 per gallon on an energy basis.

No provision was made in this feasibility study for experimental work; however, fifteen hours of test operation was done on a small diesel having 23 to 1 compression ratio. It performed well using the dual-fuel cycle, in which powdered forage was aspirated into the cylinder with the air stream and the Bosch pump injected a minimum anount of fuel oil to control ignition and timing. On inspection the engine showed no ill effects. No modifications were made on the engine.

This concept deserves a full-scale engine performance and endurance evaluation. The University of Illinois Mechanical and Agricultural Engineering Departments are well equipped to conduct such tests. It is hoped that funding can be obtained.

Projected Completion Date

Not fixed.

Title: Bio-Energy Conversion Systems - Phase III

Performing Organization:	University of Illinois Department of Forestry
Principal Investigator:	Mr. Lester E. Arnold University of Illinois Department of Forestry Dixon Springs Experiment Station Simpson, IL 62985 (618) 965-2441
Sponsoring Organizations:	University of Illinois IL Department of Energy and Natural Resources
Project Location:	Dixon Springs Experiment Station Simpson, Illinois 62985

Project Description

The Dixon Springs Experiment Station is conducting research on the feasibility of utilizing crop residues for agricultural grain drying and space heating applications. Testing on phase two with the Sukup Biomaster furnace is complete and the report is drafted. Problems were encountered with high moisture (30%) fuels, causing feeding jams and underfloor perforation clogging from ash buildup (there is no heat exchange on the model). Modifications to a forage wagon now allows on-board drying of fuel, and modifications were made to the feed and firebox control switches to allow higher moisture fuel to be used. Grain quality analysis is being conducted to determine ash buildup and effects. Testing is continuing on the Sukup unit and a newly installed M-80 Agri-Furnace biomass grain dryer system.

Phase three of this three-phase research includes the following:

1. Complete pilot phase comparative testing of a 1,000-bushel batch corn drying operation using the paired biofuel furnace and propane furnace systems. Replicate test procedures as grain volume, residue availability, harvest conditions and schedules, and technological feasibility permit.

2. As conditions permit, test fire at least one paired batch run, utilizing the biofuel furnace fuel with woody biomass energy crops available from another university project.

3. As conditions permit, test fire to capacity a pair of 6,000-bushel batch bin/dryer facilities utilizing corn crop residue as the fuel source.

4. Test fire to capacity a pair of 6,000-bushel batch bin/dryer facilities utilizing soybean residue as a fuel feedstock.

5. Conduct an initial technical and economic analysis on preliminary research data resulting from the comparative testing of a prototype biomass-fueled grain drying system for:

   a) grain moisture content and quality before and after drying;

   b) comparative evaluation for biomass fuels harvested, stored, processed, and utilized for combustion;

   c) equipment capital and operating costs, evaluation of ease and efficiency of equipment operation for various residues;

   d) manpower requirements and technical knowledge needs for equipment operation;

   e) climatic factors - ambient air temperatures, humidity, rainfall and other conditions which influenced grain and residue quality, and collection and drying equipment operation;

   f) examination of potential soil erosion factors associated with partial residue removal practices and conservation methods/alternatives to alleviate soil erosion problems.

Projected Completion Date:

January 1985

Title: Combustion of Agriculturally-Derived Nonpetroleum Fuel in Diesel Engines

Performing Organization: Agricultural Experiment Station, University of Illinois

Principal Investigator(s): Dr. Carroll E. Goering
100 Agricultural Engineering
University of Illinois
1208 W. Peabody Dr.
Urbana, IL 61801 (217) 333-2969

Sponsoring Organization: USDA and Illinois Soybean Program Operating Board

Project Location: University of Illinois

Project Summary

Objectives:

1. to screen agriculturally-derived solvents, vegetable oils and their blends as to suitability for use as fuel for diesel engines;
2. to further evaluate the most promising candidate fuels from Objective 1 through use of engine dynamometer tests; and
3. to evaluate the one most promising nonpetroleum fuel in field tests and to demonstrate its use to farmer clientele of the University.

A technique was developed for measuring energy release rates from fuels. Alcohols in soyoil-diesel blends lowered the cetane rating, increased the ignition delay and consequently increased the amount of premixed burning. Conversely, the alcohols decreased the diffusion burning. Premixed burning is more efficient but also produces greater engine stress.

An AC 190 diesel tractor was operated more than 500 hours on a methyl ester of soybean oil. No difficulties were experienced in handling or burning the fuel. However, sufficient fuel dilution occurred under light loads to require changing the lubricating oil more frequently than the normal 100-hour interval. The engine was disassembled and appears in good condition, except movement of injector needles appears to be sluggish.

Projected Completion Date

April 1984

Related Publications

Goering, C.E. and M.J. Daugherty. "Energy accounting for eleven vegetable oil fuels." ASAE Transactions (publication pending, 1982).

Goering, C.E., A.W. Schwab, M.J. Daugherty, E.H. Pryde and A.J. Heakin. "Fuel properties of eleven vegetable oil fuels." ASAE paper 81-3579, ASAE, St. Joseph, Michigan, 1981.

Title: The Effect of Nonpetroleum Fuels on Durability of Direct-Injection Diesel Engines

Performing Organization: Agricultural Experiment Station
University of Illinois

Principal Investigator(s): Dr. Carroll E. Goering
100 Agricultural Engineering
University of Illinois
1208 W. Peabody Dr.
Urbana, Illinois 61801 (217) 333-2969

Sponsoring Organization: DOE/USDA and Illinois Soybean Program Operating Board

Project Location: University of Illinois

Project Summary

Objectives:

1. to develop an automated test stand for conducting the variable-load, variable-speed, 200-hour durability test recommeded by the Engine Manufacturer's association; and

2. to use the test stand and EMA recommended test to evaluate the durability of diesel engines operating on nonpetroleum diesel fuel blends.

The 200-hour tests have been completed on diesel fuel and on three experimental fuels. One experimental fuel was a solution of soybean oil, butanol and diesel fuel. Another was a microemulsion of the preceeding components plus 190-proof ethanol. The third was a solution of soybean oil and Stoddard solvent. Engines running on the experimental fuels completed the 200-hour test successfully. However, the experimental fuels produced much heavier carbon deposits in the engine than diesel fuel. Deposits on the injector tips formed conical trumpets around the orifices and may have seriously degraded injector performance if the test duration had been extended.

Projected Completion Date

April 1984

Related Publications

Woodworth, G. and C.E. Goering. "A digital controller for automated engine testing." ASAE paper 82-3044, ASAE, St. Joseph, Michigan, 1982.

Title: A Practical System for the Use of Alcohol in Diesel Engines

Performing Organization: Dept. of Mechanical & Industrial Engineering
University of Illinois

Principal Investigator(s): Professor S.C. Sorenson
Professor L.D. Savage
Professor R.A. White
Dept. of Mechanical & Industrial Engineering
1206 W. Green St.
Urbana, Illinois 61801 (217) 333-6342

Sponsoring Organization: IL Department of Energy and Natural Resources

Project Location: University of Illinois

Project Summary

Objectives:

1. to develop a microprocessor controlled system for the fumigation of alcohol in a turbo-charged, direct injection diesel engine;
2. establish the maximum allowable amount of alcohol which can be fumigated without significant deterioration of engine performance for the entire engine operating range and different alcohol proofs;
3. develop a fumigation control strategy and microprocessor software to deliver the maximum allowable fumigated alcohol.

A computer-controlled engine test stand and data acquisition system is being constructed to develop the large data base necessary for design and construction of the alcohol fumigation system. The data base will consist of performance, fuel consumption, cylinder pressure, combustion rate, and exhaust emission data as functions of engine speed and load. These data will be collected for varying ratios of fumigated alcohol to diesel fuel and several alcohol proofs. Limits on engine efficiency, exhaust emissions, cylinder pressures, and other parameters will be used to establish the maximum allowable alcohol/diesel fuel ratio throughout the engine operating range. The microprocessor controlled alcohol fumigation system will be programmed to inject this amount of alcohol, using relevant engine parameters as input.

An International Harvester DT 436 engine is being used for system development.

Projected Completion Date

March 1986

Related Publications

None

Title: Reducing Dependence of Tractors on Petroleum Fuels

Performing Organization: Department of Agricultural Engineering
University of Illinois

Principal Investigator(s): Dr. Carroll E. Goering
100 Agricultural Engineering
University of Illinois
1208 W. Peabody Dr.
Urbana, Illinois 61801 (217) 333-2969

Sponsoring Organization: Agricultural Experiment Station, University of Illinois

Project Location: University of Illinois

Project Summary

Objectives:

1. to investigate methods for increasing the fuel use efficiency of internal combustion engines;
2. to develop improved methods for burning ethanol in tractor engines;
3. to uncover and solve problems associated with burning vegetable oils in diesel engines; and
4. to investigate unconventional engines suitable for burning solid biomass fuels.

Soybean oil is much more viscous than diesel fuel and therefore does not atomize as finely when sprayed by diesel injection nozzles. Use of experimental data in a model of the injection process revealed that atomization was aided by retarding the injection timing. Depending on injection parameters, the model predicted limits ranging from 0 to 34 percent in the concentration of soybean oil blended with diesel fuel if proper atomization was to be achieved in a DI diesel engine.

A methyl ester of sunflower oil gave more premixed burning and less diffusion burning than diesel fuel or a diesel-sunflower oil blend. Ignition delays differed little between the fuels. The implication from the heat release studies was that the methyl ester formed decomposition products which burned more rapidly than those of the other fuels.

Projected Completion Date

October 1985

Related Publications

Goering, C.E. and D.R. Wood. "Overfueling a diesel engine with carbureted ethanol." Trans. of ASAE (in press, 1982).

Shropshire, G.J. and C.E. Goering. "Ethanol injection into a diesel engine." Trans. of ASAE (in press, 1982).

Boruff, P.A., A.W. Schwab, C.E. Goering, and E.H. Pryde. "Evaluation of diesel fuel-ethanol micro-emulsions." Trans. of ASAE, 25(1):47-53, 1982.

Shirvani, H., C.E. Goering and S.C. Sorenson. "Performance of alcohol blends in diesel engines." SAE Paper 810681. Society of Automotive Engineers, Warrendale, Pennsylvania, 1981.

Title: The Utilization of Two-Year, Short-Rotation Deciduous Biomass for Energy, Particleboard, Paper and Chemicals

Performing Organization: University of Illinois
Agricultural Experimental Station
Department of Forestry
Urbana, IL 61801

Principal Investigator(s): Poo Chow and Gary L. Rolfe
110 Mumford Hall
1301 W. Gregory Dr.
University of Illinois
Urbana, Illinois 61801 (217) 333-6670 or
(217) 333-2770

Sponsoring Organization: USDA

Project Location: University of Illinois
Urbana, IL 61801

Project Summary

Two-year-old sycamores established at 9- and 12-inch spacing were harvested for various tests. Bark acounted for an average 16 percent of the stem weight. Of the total above-ground weight, 93 percent was main stem and 7 percent branches. Specific gravity of the two-year sycamore averaged 0.64 for oven-dried weight and volume. It was higher than the 0.52 for the matured sycamore lumber. It indicated that the juvenile sycamores contained more solid material than matured sycamore wood on the basis of weight per unit volume. The average heat value was 7,659 Btu per pound for two-year sycamores and 7,472 Btu for the commercial sycamore wood. Stem bark alone had a slightly higher heat value than branches and stem wood. Commercial coal had a greater heat value than any of the other materials tested. By direct combustion, 1.6 pounds of dry, short-rotation sycamore yields about the same amount of heat as 1 pound of commercial grade coal. Coal had an average ash content of 13.5 percent which was 10 times greater than that of the sample trees. Coal also had the highest sulfur content, averaging 2.2 percent. In sample trees, the percentage of sulfur was negligible. Both lignin and extractive contents were positively correlated with heat content of the sample trees. It appears that chemical composition effects heat content of wood biomass.

Test results obtained from seven 2-year-old woods and commercial lumbers indicated that all chemical properties did vary with species, above-ground tree portions and ages of specimens. Both bark and branches of young trees had a higher average gross heat value, sulfur content, ash, lignin and three extractives content than those of the stemwood. However, the stemwood portion was found to be rich in holocellulose, alpha-cellulose and pentosan content.

Tests related to the effect of planting spacing (9 in. x 9 in. and 12 in. x 18 in.), site (upland and bottomland), tree portion (stemwood and mixture of branch, bark and stemwood) and tree species (autumn olive, black alder, black locust, eastern cottonwood and sycamore) on some chemical properties were determined. Results indicated that there was little variation of chemical composition among spacing-site relationships, but that most variation occurred among species types and portion of the tree. In general, the mixture portions of each species-site type were higher in ash, extractives and lignin content, while stemwood alone was higher in holocellulose and alpha-cellulose. Eastern cottonwood had the highest content of ash and all three extractives, while the ash and extractives contents of autumn olive and sycamore were lower. Autumn olive and black alder had the highest lignin content.

Projected Completion Date

December 31, 1985

Related Publications

Chow, P., G.L. Rolfe, T.A. White and C.S. Lee. "Energy values of juvenile sycamores." Illinois Research, 22(4):12-13, 1980.

Chow, P. and G.L. Rolfe. "Utilization of woody biomass for energy." Proceedings, Energy Research Symposium, Illinois Agricultural Experiment Station, University of Illinois, Urbana, Illinois, February 5, 1981, 275 pp.

Chow, P., G.L. Rolfe, C.S. Lee and T.A. White. "The chemical properties of 2-year-old deciduous species. The Ninth Cellulose Conference, State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1982.

Chow, P., G.L. Rolfe, C.S. Lee and T.A. White. "Some physical properties of 2-year-old hardwood biomass grown in Illinois." Abstract. FPRS Annual Meeting, Forest Products Res. Soc., Madison, Wisconsin, 1982.

Chow, P., B. Motter, G.L. Rolfe, and T.A. White. "Effects of spacing and site on some physical and chemical properties of wood from short rotation forestry." Energy Research Symposium, Agricultural Experiment Station, College of Agriculture, University of Illinois, April 27, 1982.

Chow, P., G.L. Rolfe, and L.E. Arnold. 1983. "Chemicals, fiber and energy from woody biomass." Illinois Research, 25(1):11-13.

Chow, P., G.L. Rolfe, and T.F. Wei. 1983. "The ultimate and proximate analysis of some juvenile deciduous wood biomass." Book of Abstracts. 186 American Chemical Society National Meeting, Washington, D.C. (Cellulose, Paper, and Textile Division).

Title: Combustion Studies of Green Sawdust and Clean, Fine Coal Mixtures

Performing Organization:	Hardwood Processing Project North Central Forest Experiment Station Forest Service U.S. Department of Agriculture Department of Thermal & Environmental Engineering Southern Illinois University-Carbondale
Principal Investigator(s):	Howard N. Rosen Forest Service, USDA Forestry Sciences Laboratory Southern Illinois University Carbondale, IL 62901 (618) 453-2318 Wayne A. Helmer Department of Thermal & Environmental Engineering Southern Illinois University Carbondale, IL 62901 (618) 536-2396
Sponsoring Organization:	None
Project Location:	Wood Processing Pilot Plant Carterville, Illinois

Project Summary

Currently, about 20 to 40 percent of all the energy consumed by sawmills is generated on-site through combustion of wood wastes. The wood industry will need to utilize even more of its wood residues if energy costs are to be kept at a reasonable level. Over 24 million tons of unused mill residues are generated every year at primary wood processing plants in the United States. Little use has been found for these wood residues apart from energy production. Since the lumber industry is becoming more efficient in its wood processing, less wood residue will be available for fuelwood in the future. Other industrial waste can be combined with the wood residue to extend its energy generation potential. Basic research is necessary to further utilize lumber mill residues and refuse-derived fuel for energy production.

The objective of this study is to determine how fuel particle size, underfire air flow rate, and coal-to-wood ratio affect the combustion efficiency and emissions in a controlled combustion chamber. A small-scale burner system will be constructed. Dry, clean, and fine high-sulfur coal will be burned with sawdust of a specific moisture content. Carbon carry-over rate, burning rate, particulate emission rate, and gaseous emission rate will be determined from gas chromatography measurements, particulate measurements, and temperature measurements.

Projected Completion Date

Fall 1987

SOLAR HEATING AND COOLING: PASSIVE DESIGNS

Title: Calibrated Hot Box Test Results Data Manual

Performing Organization: Construction Technology Laboratories (CTL)

Principal Investigator(s): Martha G. Van Geem
Construction Technology Laboratories
5420 Old Orchard Road
Skokie, Illinois 60077
(312) 965-7500

Sponsoring Organization: Oak Ridge National Laboratory for
U.S. Department of Energy
Portland Cement Association

Project Location: Skokie, Illinois

Project Summary

Twenty-one walls have been tested in the calibrated hot box test facility at Construction Technology Laboratories, a division of the Portland Cement Association. Test results are being summarized in a Calibrated Hot Box Test Results Data Manual.

The calibrated hot box provides data on the heat transmission characteristics of full-size wall assemblies under steady-state and dynamic temperature conditons. Steady-state tests are used to obtain average heat transmission coefficients. Dynamic tests provide data on thermal performance under controlled conditions that simulate actual temperature changes in building envelopes. Thus, dynamic testing provides a comparative measure of thermal response and also can verify analytical models for transient heat flow. Calibrated hot box tests are performed in general accordance with ASTM Designation: C976, "Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box."

The data manual includes a description of wall geometry and material properties for each specimen. The manual presents steady-state, transient and dynamic test results in tabular form, in figures and in summary tables. Heat transfer characteristics of different wall assemblies can be easily compared by using figures and summary tables of each wall. Data presented in numerical form can be used to validate models or analyze results. Walls tested include masonry, concrete and wood frame systems. The manual will provide a unique and comprehensive data base for engineers, architects and researchers.

Thermal storage mass in a passive solar system absorbs, stores and releases heat. Concrete and masonry walls are frequently used as the thermal storage mass. Laboratory tests of walls under dynamic temperature conditions can be used to evaluate wall thermal performance.

Projected Completion Date

February 1984

Related Publications

Fiorato, A.E. and E. Bravinsky. "Heat transfer characteristics of walls under Arizona temperature conditions." Construction Technology Laboratories, Portland Cement Association, Skokie, 1981, 61 pages.

Fiorato, A.E. and C.R. Cruz. "Thermal performance of masonry walls." Research and Development Bulletin RD071, Portland Cement Association, Skokie, 1980, 17 pages.

Fiorato, A.E. "Heat Transfer Characteristics of Walls Under Dyamic Temperature Conditions," Reseach and Development Bulletin RD075, Portland Cement Association, Skokie, 1981, 20 pages.

Van Geem, M.G., A.E. Fiorato and D.W. Musser. "Calibrated hot box tests of thermal performance of concrete walls." Proceedings of the ASHRAE/DOE-ORNL Conference on Thermal Performance of Exterior Envelopes of Buildings II, Las Vegas, December 1982, ASHRAE SP38, Atlanta, 1983, pp. 108-130.

Title: Calibrated Hot Box Tests of Thermal Performance of Concrete Walls

Performing Organization: Construction Technology Laboratories (CTL)

Principal Investigator(s): Martha G. Van Geem
Construction Technology Laboratories
5420 Old Orchard Road
Skokie, Illinois 60077
(312) 965-7500

Sponsoring Organization: Oak Ridge National Laboratory for
U.S. Department of Energy
Portland Cement Association

Project Location: Skokie, Illinois

Project Summary

A normal-weight concrete wall with board insulation applied to one face will be tested in the calibrated hot box facility (ASTM Desingation: C976) at the Construction Technology Laboratories, a division of the Portland Cement Association.

This work will conclude a program that involved testing three concrete walls in addition to the wall with board insulation. Normal weight, structural lightweight, and low-density concrete walls were tested. These concretes had unit weights ranging from approximately 50 to 145 pcf. Thermal conductivity of the concretes, derived from calibrated hot box tests, ranged from 1.5 to 12.0 Btu-in./hr.ft^2-°F. The R-value of the normal-weight concrete wall with board insulation will be approximately equal to the R-value of the low density concrete wall.

The concrete wall with board insulation will be subjected to steady-state, transient and periodically varying temperature conditions. Steady-state tests are used to define heat transmission coefficients such as U- and R-values. Data obtained during transient and periodic temperature variations are used to define dynamic thermal response of the wall. This response includes heat storage capacity as well as heat transmission characteristics of the wall assembly.

Laboratory test results will be used to define thermal characteristics of walls in passive solar systems. Information from this project will also provide a data base for evaluation of building envelope performance where normal-weight concrete walls with board insulation are used.

Projected Completion Date

August 1984

Related Publications

Van Geen, M.G., A.E. Fiorato and J.T. Julien. "Heat transfer characteristics of a normal-weight concrete wall." Construction Technology Laboratories, Portland Cement Association, Skokie, 1983, 89 pages.

Van Geem, M.G., A.E. Fiorato. "Heat transfer characteristics of a structural lightweight concrete wall." Construction Technology Laboratories, Portland Cement Association, Skokie, 1983, 88 pages.

Van Geem, M.G. and A.E. Fiorato. "Heat transfer characteristics of a low density concrete wall." Construction Technology Laboratories, Portland Cement Association, Skokie, 1983, 89 pages.

Title: Lightweight Concrete Used as a Structural, Insulating, and Energy Storage Element

Performing Organization: Construction Technology Laboratories (CTL)

Principal Investigator(s):
Martha G. Van Geem
Albert Litvin
Construction Technology Laboratories
5420 Old Orchard Road
Skokie, Illinois 60077
(312) 965-7500

Sponsoring Organization: Pacific Northwest Laboratories, Battelle Memorial Institute for the U.S. Department of Energy

Project Location: Skokie, Illinois

Project Summary

The objective of this research is to develop a portland cement concrete for use in low rise building walls that would combine the structural, thermal insulating, and heat storage capacity functions of the walls.

Dynamic thermal performance of walls is dependent on three material properties. Generally, the lowest heat transmission is found in a wall with low thermal conductivity, high specific heat, and heavy weight. However, thermal conductivity of concrete increases with unit weight. Since heat transmission properties are sensitive to changes in thermal conductivity, which is related to changes in unit weight, the lighest concrete that has sufficient structural capacity will be used to satisfy this concept.

Expanded clay and shale coarse aggregates were used with expanded polystyrene beads and perlite fine aggregates to obtain concretes having air dry unit weight of less than 65 pcf with compressive strengths in the range of 2000 psi. Specific heat and hot wire thermal conductivity tests were performed on concrete from the three mixes with the most desirable combinations of low unit weight, and high compressive strength. Dynamic thermal properties of diffusivity, lag, and reduction in amplitude of peak heat flow were estimated.

Projected Completion Date:

May 1984

Title: Measurement of Thermal Response of a Masonry Cavity Wall Using a Calibrated Hot Box

Performing Organization: Construction Technology Laboratories (CTL)

Principal Investigator(s): Martha G. Van Geem
Construction Technology Laboratories
5420 Old Orchard Road
Skokie, Illinois 60077
(312) 965-7500

Sponsoring Organizations: Brick Institute of America
National Concrete Masonry Association
Perlite Institute, Inc.

Project Location: Skokie, Illinois

Project Summary

A 12-in. block-brick cavity wall is being tested in the calibrated hot box facility (ASTM Designation: C976) at the Construction Technology Laboratories, a division of the Portland Cement Association. The wall is constructed of 6-in. hollow concrete block and 4-in. clay brick. Laboratory tests are being performed on the wall with and without perlite fill in the cavity.

The wall is being subjected to steady-state, transient and periodically varying temperature conditions. Steady-state tests are used to define heat transmission coefficients such as U- and R-values. Data obtained during transient and periodic temperature variations are used to define dynamic thermal response of the wall. This response includes heat storage capacity as well as heat transmission characteristics of the wall assembly. Test data will also be used to determine the effects of perlite insulation in the cavity.

The cavity wall construction is similar to that used in a test cell monitored by the National Bureau of Standards (NBS) in Gaithersburg, Maryland. Two of the dynamic temperature cycles that are being applied to the wall during laboratory tests were derived from actual wall surface temperatures at the NBS test cell. Heat flow meter data from the test cell will be compared to calibrated hot box test results.

Laboratory test results will be used to define thermal characteristics of walls in passive solar systems. Information from this project will also provide a data base for evaluation of building envelope performance where cavity walls are used.

Projected Completion Date

January 1984.

Title: Alternate Home Energy Application and Demonstration Project

Performing Organization: Illinois Central College

Principal Investigator(s): D. Louis Brooks-Miller
Illinois Central College
East Peoria, IL 61635 (309) 694-5011

Sponsoring Organization: U.S. Department of Energy

Project Location: East Peoria, Illinois

Project Summary

Illinois Central College has constructed a demonstration and experimental free-energy house. Located on college property near present instructional facilities, the house will provide a viable educational laboratory from which to educate students, faculty and the general public to the need and feasibility of using free energy from nature. As much as possible, this facility will fit into the total environment by neither taking from nor adding to its surroundings. Designed to provide both active and passive energy utilization examples, the house will serve as a model of the latest technology in alternative energy utilization. Adequate monitoring equipment will be provided in order to ascertain actual performance data relative to the various types of active and passive energy-using devices. This data will be shared with contractors, prospective home builders and homeowners desiring information about possible conversion of existing consumable energy burning devices to either passive or active alternate devices.

The Architectural Construction Technology students at Illinois Central College have augmented the original project by installing a pair of Zomeworks shutters in the direct gain area, two collectors on the roof for the domestic hot water system, wooden shutters at north exposure, and a heat sink in the greenhouse. Two retrieved farm windmill towers are being installed south of Dirksen Hall on campus for later attachment of generating devices.

Projected Completion Date

N/A

Title: Continued Development of an Effective Commercial-Size Solar
Greenhouse for Productive and Profitable Use in Illinois

Performing Organization: The Stelle Group

Principal Investigator(s):
Timothy Wilhelm
The Stelle Group
Administration Building
Stelle, IL 60919
815/256-2200

Sponsoring Organizations:
Illinois Department of Energy and Natural Resources
Dow Chemical Company

Project Location: Stelle, Illinois

Project Summary

This project proposes to construct, operate and monitor a commercial-size greenhouse incorporating several innovations for solar greenhouses. The system will have double glazing on its south side, an insulated protective barrier on its north side and heavily insulated end walls.

The thermal mass/heat storage system will consist of water contained in 55-gallon drums and phase change salts stored in a sealed "bladder" of thin, flexible, impermeable film of butyl rubber.

The greenhouse will utilize a new technique for supplying nocturnal insulation. The insulation used in this new system is a temporary liquid foam which is formed and held in place by a small air blower. It can be automatically controlled with a photo-electric switch and every night the entire space between the two layers of glazing will fill with a mass of tiny bubbles. In the morning, the foam is allowed to dissipate and the liquid which formed the bubbles runs down into its containing trough as the bubbles break. It has been experimentally indicated that a 6-inch space between two layers of glazing would become approximately an R-15 barrier when the foam wall is erected.

It is estimated that these design innovations will result in a 70 percent reduction in fuel consumption when compared to a double-poly house and over a 90 percent reduction when compared to a single-layer glasshouse.

Projected Completion Date:

March 1986

Title: Evaluate Air Envelope - Solar Home

Performing Organization: Illinois Power Company

Principal Investigator(s): H.J. Rand
Illinois Power Company
500 South 27th Street
Decatur, Illinois 62525 (217) 424-6872

Sponsoring Organization: Illinois Power Company

Project Location: Bloomington, Illinois

Project Summary

Check metering was installed to determine space conditioning and water heating energy requirements of an air envelope-solar type residential house. Data analysis will include the use of BLAST energy analysis program to complete the evaluation of this type of construction in central Illinois. This project also includes the evaluation of earth tube cooling, as well as passive solar heating.

Projected Completion Date

1985

Related Publications

None

Title: Thermodon Passive Solar Project

Performing Organization: National Concrete Masonry Association (NCMA)
2302 Horse Pen Road
P.O. Box 781
Herndon, Virginia 22070 (703) 435-4900

Swenson and Chang, Architects
18 South Michigan
Chicago, IL 60603 (312) 782-9172

Principal Investigator(s): Bion D. Howard, NCMA
Kevin D. Callahan, NCMA
Alfred J. Swenson
Pao-Chi Chang

Sponsoring Organizations: National Concrete Masonry Association (NCMA)
U.S. Department of Energy
IL Department of Energy and Natural Resources

Project Location: (To be determined 6/84)

Project Summary

Energy savings from passive solar utilization in multi-family residential structures such as apartment complexes, low-cost housing and condominiums is an area of tremendous potential for urbanized regions.

The Thermodon concept, developed by Dr. A. Swenson and Dr. P. Chang, Architects, attempts to answer critical questions regarding the use of an integrated system of structural concrete masonry using passive/hybrid solar heating and natural cooling for buildings up to nine stories high.

The structure itself is to be constructed of materials which will reduce energy use for space conditioning while providing enhanced thermal comfort and structural strength.

Computer analysis of the system produced results showing Thermodon would use only about 19,000 Btu/ft^2-year. This annual "energy budget" includes all heating, cooling, lighting and appliances. Additional operating energy for air-circulation and the control of the passive/hybrid solar collection subsystem would be very small. Comparable buildings (multi-family housing units) would consume about 60,000 Btu/ft^2-year in the Chicago area, according to a survey of buildings by IIT, for 1975-1978.

Project Description

The Thermodon system is to be tested using a prototype residential structure of similar design and construction, with 3,100 square feet of usable floor area, built in Chicagoland.

The building will be monitored approaching Class A (SERI) specifications through the use of an Aeolian Kinetics (Providence, Rhode Island) PDL24/C data acquisition system logging 82 channels of data. One-time measurements will be taken in detail at Thermodon. Temperatures, auxiliary fuel use, control system status, solar radiation, weather conditions and resulting indoor comfort are to be measured. The results will be computer analyzed to determine the building energy balance, solar fractions, thermal integrity, comfort (after Fanger) and comparative performance to other passive/hybrid solar buildings.

Results and data will be reported in formats consistent with SERI, LBL and Vitro reporting for the Class B and Class A programs. Recipients of data are to be U.S. Department of Energy and Illinois Department of Energy and Natural Resources. Analysis will furnish suggestions for improving performance, comfort and construction cost-effectiveness of Thermodon systems, "scaled up" to their full multi-family size. Performance testing on a reduced scale; using an occupied unit should give results which will allow very accurate estimates of the performance of the full-size application.

Building Description

The test building will be constructed of concrete block developed for the purpose of loadbearing, with cavities for horizontal and vertical air movement in the area enclosed by two double face shells.

The walls will be insulated on the outside and solar-heated or naturally cooled air will be impelled through them using small fans controlled by thermal sensors to optimize flows.

The roof-ceiling sections will also act as structural and thermal components by allowing air flow through the hollow cores of precast concrete floor planks, impelled by the same fan system which drives the wall circulation.

Solar glazings fitted on the south side of the structure are to be controlled by insulated curtain wall systems of R11, when closed. The south walls will also have operable windows for summer cross-venting. The control system will position the curtains up during the day in winter for solar collection. The same controls, reset for summer, will position the curtains down during the day to reduce unwanted gains to the south side of the unit.

The north side of the structure will have somewhat smaller windows, comprised of patio doors. The heat losses of these openings are also to be controlled by curtain walls. During winter, these would be closed unless manually overridden, greatly reducing the load on the north side. During summer the curtains are open when net losses can be provided to cool the indoor space. Dampers to control air flow through the floor planks are coordinated with the north curtain operations in summer. The air used to cool the floor and walls is "dumped" out the north side in summer. Air flow during heating modes is recycled through the indoor area, back to the solar collector zone.

Project Completion Dates

Site Selection: June 1984
Construction: September 1984
Monitoring: January 1985 - October 1986
Final Report: January 1987

Publications

Howard, Bion D. "Thermodon Passive Solar Project: Progress and Status Report." (September 28, 1982 to February 28, 1983), U.S. Department of Energy, DOE/CS/30756-01, 1983.

Howard, Bion D. "Thermodon Passive Solar Project: Project Status Report." (March 1, 1983 to March 31, 1983), U.S. Department of Energy, DOE/CS/30756-02, 1983.

Kim, J.K. "Concrete Masonry Mid-Rise Buildings With Solar Heating and Natural Cooling." Graduate Thesis (MS), Illinois Institute of Technology, Chicago, Illinois, 1981.

Title: The "Illinois Lo-Cal House"

Performing Organization:	University of Illinois Small Homes Council Building Research Council
Principal Investigator(s):	Michael McCulley, SHC-BRC, (217) 333-1801
Sponsoring Organizations:	IL Department of Energy and Natural Resources U.S. Department of Energy
Project Location:	4003 Farmington Drive Champaign, IL 61820

Project Summary

The Small Homes Council-Building Research Council of the University of Illinois is currently involved in a project to collect thermal performance data on two occupied, super-insulated, passive solar light-frame residences in Champaign, Illinois. A further objective of this project is to test the effectiveness of the energy-saving design features incorporated in the "Illinois Lo-Cal House." The Lo-Cal design incorporates two basic concepts:

1. a heavily insulated envelope with low infiltration, featuring a double staggered stud wall configuration, triple glazing on all windows, and a polyethelyne vapor and infiltration barrier; and

2. solar orientation; featuring a majority of the glass facing south, the major axis of the house oriented east-west and roof overhang designed to optimize solar input.

The test residence is heavily instrumented to monitor the thermal performance of the building envelope, the interior comfort conditions and the energy use in response to exterior climatic conditions.

The heart and brain of the data acquisition system is the Hewlett-Packard HP3497 Data Acquisition/Control Unit and the HP85A Desktop Computer. The system features interrupt capabilities, a small CRT display, graphics capabilities which can be used for quick graphical data summaries, a printer, and cassette tape storage.

All sensors are scanned sequentially at 5-minute intervals with the data being averaged every 15 minutes. These averaged values are stored locally on cassette tape and transferred to the University's main computer on a regular basis.

August 1980 - December 1981: Instrument Set-Up

Instrumentation equipment was acquired and installed. The computer program and instrumentation was tested, calibrated and debugged.

December 1981 - September 1982: Data Collection

During this period, data was collected from the sensors in the process described earlier. The data was tabulated and analyzed, using the main computer at the University of Illinois. Selected days were set aside for the testing and calibration of instruments, furnace equipment and the structure.

March 1982: Thermal Performance Experiments

In order to test the energy-saving features incorporated in the "Lo-Cal" design, it was necessary to determine the overall insulating effectiveness of the building under various controlled operating modes. The Building Thermal Performance (UA-value divided by floor area) is a measure of overall resistance to heat loss. The lower the performance value, the more energy-efficient the building is.

For the experiment, space heaters in each room were used to keep the interior temperature constant during the test period. An energy balance was performed to calculate the UA-value for different operating modes. For the base house with the furnace fan off, the performance was .779/Wm^2 k (3.3 Btu/ft^2 DD), with approximately 77 percent of the heat loss through the building envelope, and 23 percent by infiltration. With the fan on, the losses increased by 27 percent to .987 W/m^2k (4.18 Btu/ft^2 DD), 61 percent of the heat loss due to the building envelope. Shuttering the windows decreased the losses by 7 percent to .722 W/m^2k (3.1 Btu/ft^2DD).

September 1982 - August 1984: Future Plans

From the performance experiments, it was found that a substantial amount of heat loss is due to infiltration and to losses to the crawl space from the furnace and duct system. Therefore, in the winter of 1982, the ducts in the crawl space will be insulated and the furnace closet will be sealed off. A fresh air inlet from the attic to the furnace closet will be installed. Data will then continue to be collected and the effect of these changes will be analyzed.

Further research includes building a connected greenhouse and analyzing its effect on energy use. Also, the Small Homes Council-Building Research Council has entered into an agreement with Brookhaven Laboratories to analyze the data and develop a joint publication concerning the project. This phase will be completed in August 1983.

Projected Completion Date

Summer 1984

Related Publications

McCulley, Michael, Alan R. Parkinson and Curtis O. Pederson. "The University of Illinois lo-cal house: computer simulation, monitoring equipment installation, data acquisition methods, and data analysis," International Conference on Comparative Experimentation of Low Energy Houses, Liege, Belgium, Spring 1981.

O'Meara, Robert James, Jr. "The relationship between building energy usage, air infiltration, and warm air supply system in a heavily insulated house," M.S. Thesis, University of Illinois, 1981.

O'Meara, Robert James, Jr., Michael T. McCulley, et.al., "A correlation study of the thermal performance of an existing passive solar building," 4th Miami International Conference on Alternative Energy Sources, Miami Beach, Florida, Winter, 1981.

Title: Quantifying the Performance of Passive Solar Heating Systems

Performing Organization: Department of Mechanical Engineering
University of Illinois at Urbana-Champaign

Principal Investigator(s): Professor A.M. Clausing
Department of Mechanical and
Industrial Engineering
College of Engineering
144 Mechanical Engineering Building
1206 West Green Street
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801 (217) 333-0366

Sponsoring Organization: University of Illinois

Project Location: University of Illinois at Urbana-Champaign

Project Summary

Three key parameters were derived for quantifying the thermal performance of passive solar heating systems: the efficiency, the effectiveness and the comfort index. The efficiency is a measure of the quality of the design; the effectiveness is an indicator of the capacity of the passive system relative to the building load; and the comfort index provides a means of judging potential discomfort due to temperature fluctuations. Models of a variety of passive heating systems are being derived and analyzed. One objective is to determine and compare the thermal performance characteristics of the many proposed designs for passive solar heating systems. A second objective is to develop a design tool for predicting the performance of passive heating systems at various locations throughout the United States.

Projected Completion Date

1984

Related Publications

Kosar, D.R. and A.M. Clausing, "Performance prediction of passive solar heating systems," Proc. 1981 Annual Meeting, American Section of ISES, Vol. 43, 1981, pp. 891-895.

Clausing, A.M. and B. Drolen, "The characterization of the performance of passive solar heating systems," Proc., ISES Int. Congr., Atlanta, Georgia, Vol. II, 1979, pp. 1540-1544.

Clausing, A.M. and B. Drolen, "Parameters for quantifying the thermal performance of passive solar heating systems," Proc., Annual ISES Meeting, Denver, Colorado, Vol. 2.2, 1978, pp. 78-83.

Title: Washburne Trade School Solar Project

Performing Organization:	Washburne Trade School Building Trades Class
Principal Investigator(s):	Cliff Lemasters Washburne Trade School 3233 W. 31st St. Chicago, Illinois 60623 312/641-4800
Sponsoring Organizations:	Illinois Department of Energy & Natural Resources Washburne Trade School
Project Location:	Chicago, Illinois

Project Summary

The Washburne Trade School project will demonstrate a house which incorporates many of the basic principles of energy-conscious design with particular emphasis on south orientation for passive and optional active solar collection and an energy efficient greenhouse large enough for family food production. The design intention is to build thermal storage capacity and thermal window closures necessary for passive solar design into the light wood frame construction which is common in the housing market.

The project will also incorporate longer term thermal storage (rock storage bed and water storage tank) in conjunction with active solar collectors and a heat pump. This thermal capacity can be used for night time cool storage to reduce summer peak loading demands. It is estimated that the combination of the systems will give a 72 percent heating load reduction.

This solar home can be considered to be a well insulated, passive solar installation - primarily direct gain. It is hybrid to the extent that a fan will be used in the greenhouse to move heated air to a rock storage bed floor located in the greenhouse. The air distributing system in the house will move heated air to remote rock storage (125 ft.^{3}) located in the crawl space which also serves as a warm air plenum. Both storage elements are intended to serve as thermal mass rather than high temperature storage.

A moveable element, located in the house portion, incorporating phase change thermal storage rods (Thermol 81) will function as an indirect solar gain system to better accomodate diurnal changes. The thermal storage wall works convectively rather than as a radiative surface. It will be a free-standing movable wood casework enclosre (6 ft. x 12 ft. x 6 in.) hinged in two or four sections for off-season compaction. The wall will have a transculent plastic exterior face cover with top and bottom vents that will provide better control in a room that would otherwise be direct gain heated.

A passive solar hot water tank will also be located in the greenhouse to serve as an additional thermal ballast and to reduce domestic hot water demand.

An active solar collection system consisting of three 4 ft. x 8 ft. panels mounted horizontally will be used for space heat supplement. A movable shade cloth will be used to cover the collectors when the extra heat is not required. The active solar system will be a Solar Energy Products liquid system sized for domestic hot water usage. This system will be large enough for this project since the house will not be occupied. The purpose is to demonstrate the feasibility of using this type of system for supplemental space heat.

A large water storage tank (82 gallons) with a double walled heat exchanger will be fed by the active collectors and excess heat from the greenhouse. This will be used to help further reduce the heating and cooling demands. The water source heat pump will draw heat from and dump summer rejected heat into the water storage tank.

Roof overhangs will minimize window gains in the summer. Operable loft windows will provide natural ventilation.

The solar control and temperature sensing system has been developed by Solar Energy Systems, Inc. for Washburne Trade School in cooperation with Energy Bond Fund staff at the Illinois Department of Energy and Natural Resources. Thermisters will be used to measure the active collector inlet and outlet temperatures; the heat exchanger inlet and outlet temperatures; storage tank water temperature; rock storage temperature; and space temperatures in the greenhouse, family room, living room, bedrooms, loft, attic, crawl space and garage. A watt-meter will be used to measure the electrical usage and a gas flow meter will measure the gas usage.

Integrating all the collected data for analysis and presentation still remains a concern of the school. Presently plans to purchase a computer and automate data collection will simplify the manual efforts they use now. Throughout the summer the groundwork was laid for this switch in monitoring technique and now that school has resumed, the intensity of the project activity will also increase.

Projected Completion Date

December 1984

Related Publications

None

SOLAR HEATING AND COOLING: AIR HEATING

Title: Comparison of On-Site Built Forced Air Solar Collectors

Performing Organization: Community Energy Systems, Inc.

Principal Investigator: William Winberg
Community Energy Systems
1820 South MacArthur Blvd.
Springfield, IL 62704 (217) 522-2836

Sponsoring Organizations: Illinois Department of Energy
and Natural Resources
Community Energy Systems

Project Location: Springfield, Illinois

Project Summary:

The Community Energy System (CES) solar project involves the performance testing of three designs of site-built air solar collectors. These forced air collectors are typically mounted on south facing walls or roofs of existing buildings and are designed to provide supplemental space heat. Since they are constructed with locally available materials, these collectors are significantly less expensive than factory-assembled units. Their relatively low cost, and simplicity of installation, makes these panels especially attractive in the retrofit market.

Community Energy Systems has been constructing and installing these collectors for the past three years. About 20 such systems have been installed in Springfield, and they are a popular do-it-yourself energy saving project around the state. Unfortunately, site-built, vertical wall air collectors have never been tested, in Illinois or elsewhere, in order to determine their efficiency. This project will provide an accurate assessment of the actual energy output of vertical wall collectors and will help to determine the efficacy of several design modifications.

The typical vertical wall collector, as constructed by CES, consists of a 4' x 8' wooden, insulated enclosure with two layers of reinforced fiberglass glazing. Air is circulated on both sides of a corrugated aluminum absorber plate which is painted flat black. Air from an adjacent room is generally blown through the collector and returned to the same living space, although conventional ductwork can be used to heat more remote rooms. Temperature sensors in the collector and living space run the thermostatically controlled fan.

In an effort to reduce costs and improve performance, CES will be testing two other collector configurations. In the first, only one layer of glazing will be used, with the air flow occurring only behind the absorber plate. This arrangement will maintain an insulative dead-air space between the absorber and glazing. The second design will add a selective surface coating to the front of the aluminum absorber plate in a single glazed, backflow collector. Since selective surfaces have a high absortivity of solar radiation, but a low re-radiation emissivity, this design should improve the collector's performance substantially.

Each of the three collector designs will be mounted in two positions, vertically and at a 45-degree tilt angle. The variation in tilt angles will test the hypothesis that vertically installed collectors, taking advantage of additional insolation from ground reflectance, perform as well as collectors mounted at a more optimum angle. The additional cost which may be required by racks for roof mounting will be considered in a comparative economic analysis.

Tilted collectors, however, present a greater surface area to the summer sun than vertical collectors, raising the issue of possible thermal degradation of stagnating collectors during the summer months. A seventh collector, mounted at a 45-degree tilt angle, will be allowed to stagnate for 12 months. An inspection following this period will determine the extent of any structural deformations.

Another option for the tilted collectors is to utilize the incident solar radiation during the non-heating season. The three systems with tilted collectors will be fitted with an air-to-liquid heat exchanger in the hot air ducts from the collectors, in order to preheat domestic hot water when space heating is not required. These pump-assisted subsystems will be studied to determine whether the amount of hot water produced justifies the additional expense.

The CES project will provide a vast amount of information concerning the thermal efficiency and cost-effectiveness of vertical wall collectors. This information will be extremely useful to solar businesses and do-it-yourself oriented homeowners across the state. In addition to defining the most efficient designs, this government-supported research will add credibility to the practicality of these systems, which will increase consumer confidence in vertical wall collectors.

Projected Completion Date

June 30, 1985

Related Publications

None

Title: Solar-Dehumidification Drying with Heat Storage

Performing Organizations: Hardwood Processing Project,
North Central Forest Experiment Station,
Forest Service,
U.S. Department of Agriculture

Principal Investigator(s): Peter Y.S. Chen
Forest Service
USDA, Forest Sciences Laboratory
Southern Illinois University
Carbondale, Illinois 62901 (618) 453-2318

Sponsoring Organization: None

Project Location: Carbondale, Illinois

Project Summary

Two energy-efficient methods of lumber drying--the solar kiln and the dehumidifier kiln--have received much attention recently.

In solar drying, lumber is stacked in a closed chamber, heat is supplied to the kiln as air circulates across the solar collectors, and the hot, humid air is vented. Although solar energy is renewable, pollution-free and inexpensive, solar drying has several limitations: 1) a relatively large collector area is required to provide sufficient heat for moderate size kilns; 2) solar collectors cannot supply heat during cloudy periods or at night; and 3) the air-heated solar collectors supply relatively low temperature heat, thus prolonging the drying time compared to higher temperature methods.

In dehumidification drying, moisture evaporated from the wood is condensed on an evaporator coil of the refrigeration unit and is drained as water. As the water condenses, it gives up heat to the refrigerant. This heat is recovered as the kiln air passes through the condensor coil of the unit and is used to evaporate more moisture from the wood. Although a dehumidification dryer is more energy-efficient, costs less to install, and is easier to operate than a steam-heated conventional kiln, dehumidifiers have these drawbacks: 1) the system provides no means of conditioning lumber for stress relief, and 2) dehumidifier kilns use electrical energy which is more expensive than steam used in conventional kilns.

At the Forestry Sciences Laboratory in Carbondale, Illinois, we have proposed to overcome these limitations of both systems by merging solar and dehumidification drying technologies with the addition of a solar heat storage unit.

Solar-dehumidification drying is the removal of moisture from wood in a sealed chamber through evaporation and condensation steps. In this process, water in wood is evaporated by kiln air which is heated by solar collectors and the condensor coil of the dehumidifier. The moisture in the kiln air is condensed on the evaporator coil of the dehumidifier and drained off as water. The method appears promising for the following reasons: 1) a solar-dehumidifier kiln, which is a closed system, does not vent hot kiln air and thus reduces heat loss greatly, and 2) solar energy is used to reduce the consumption of the more expensive electrical energy.

We have designed and constructed a 500 bf solar-dehumidifier kiln capable of drying and conditioning standard size lumber to a temperature of 180°F. We are constructing a bed-rock heat storage unit to be added to the existing solar-dehumidifier kiln. A series of experiments will be carried out to test the effectiveness and efficiency of the system as a lumber dryer.

Projected Completion Date

Summer 1984

Related Publications

Chen, P.Y.S., E.C. Workman, Jr. and E.C. Helton. "How to build a collector for a solar kiln with aluminum cans." FPRS News-Digest, Processes: Drying and Storage, February 1978, File: G-1.14, 4 pp.

Helmer, W.A., H.N. Rosen, P.Y.S. Chen and S.S. Wang. "A theoretical model for solar-dehumidification drying of wood." Drying '80, Vol. 2, Proceedings of the 2nd International Symposium. Ed. A.S. Mujumdar. Hemisphere Publishing Corp., New York, New York, 1980, pp. 21-28.

Rosen, H.N. and P.Y.S. Chen. "Drying lumber in a kiln with external solar collectors." Amer. Inst. Chem. Eng. Symp. Ser. 200(16):82-89, 1980.

Chen, P.Y.S. "Design and tests of a 500 BF solar kiln." For. Prod. J. 31(3):33-38, 1981.

Chen, P.Y.S. "Insolation at Carterville, Illinois." U.S. Dep. Agric. For. Serv. Res. Note NC-271, 1981, 4 pp.

Chen, P.Y.S., W.A. Helmer and H.N. Rosen. "Experimental studies of solar and solar-dehumidification lumber drying." J. Energy 5(3):130-131, 1981.

Chen, P.Y.S. and H.N. Rosen. "Building an efficient solar kiln." Furniture Production 45(355):36-37, 1981.

Chen, P.Y.S. and H.N. Rosen. "Drying lumber in a solar-dehumidifier kiln." South. Lumberman 242(3016):105-107, 1981.

Chen, P.Y.S. and W.A. Helmer. "Principles of dehumidification lumber drying." For. Prod. J. 32(5):24-28, 1982.

Helmer, W.A., P.Y.S. Chen and M.B. Vaidya. "A computer model to simulate solar and solar-dehumidification lumber drying." J. Solar Energy Engin. 104(3):182-186, 1982.

Chen, P.Y.S., W.A. Helmer, H.N. Rosen and D.J. Barton. "An experimental solar-dehumidifier kiln for drying lumber." For. Prod. J. 32(9):35-41, 1982.

Chen, P.Y.S. and H.N. Rosen. "Solar-dehumidification drying of red oak." J. Inst. Wood Sci. 9(4):194-196, 1982.

SOLAR HEATING AND COOLING: WATER HEATING

Title: Midwest Pipeline Solar Project

Performing Organization: Midwest Pipeline, Inc.

Principal Investigator(s): Scott Mitchner
Midwest Pipeline, Inc.
8102 W. 44th Ct.
Lyons, IL 60534 (312) 387-7542

Sponsoring Organization: Illinois Department of Energy and Natural Resources

Project Location: Morton College
Cicero, IL

Project Summary

The Midwest Pipeline solar project originally involved the comparison of two solar collection systems for domestic hot water. Both systems used a Freon-type (Freon 114) phase change medium. One system consisted of a thermosyphoning collector in which the storage tank is physically placed above the collector. In many applications, such as roof mounts, the storage tank is not physically above the collector and therefore the system needs to be pump assisted. The second system used a 1/4 horsepower (low energy consumption) rotary vane pump to circulate the heat transfer medium.

Refrigerant-charged systems have several theoretical advantages over conventional systems. Refrigerants have the ability to absorb and transfer greater amounts of heat, due to their phase-change characteristics which allows them to take advantage of their latent heat of vaporization in addition to sensible heat transfer. This latent heat exchange produces an isothermal operation which lowers the solar collector operating temperature and thereby increases the collector efficiency. This project is designed to assess the relative thermal efficiency and practical engineering feasibility of these types of solar systems.

A thermosyphoning system operates in the following manner. Solar radiation strikes the flat, black collector absorber plate and is conducted to the liquid refrigerant which absorbs the heat, causing it to boil. In the process of boiling, great amounts of heat will be absorbed, changing the refrigerant to a vapor. Vapor pressure causes the vapor to rise to the physically higher condensor. The condensor walls conduct the latent heat of vapor to the water storage tank, causing the vapor to condense. The condensed liquid will flow due to gravity to a receiver. The liquid flows through connecting tubing to the collector intake manifold and the cycle repeats.

The pump-assisted system basically follows the same principle except that the receiver is physically well below the collector and therefore the condensed refrigerant must be mechanically pumped up to the collector intake manifold where the cycle begins again.

Midwest Pipeline, Inc. has prepared a technical report which details the problems encountered with the original configuration of the absorber plates. These problems led to material failure of the plates, resulting in redesign and relocation of the project.

Midwest Pipeline, Inc. and Morton College completed a letter of agreement on August 2, 1983 to locate the project on the Morton College campus in Cicero. The college's heating, ventilation, and air conditioning program will install a freon-charged system side-by-side with a conventional, antifreeze-charged, solar domestic hot water system. Midwest Pipeline in cooperation with college staff, will continue data monitoring of the systems. Site preparation has begun at the College and the installation racks for the collectors have been ordered.

Projected Completion Date

June 30, 1984

Title: Solar Commercialization and Training Project

Performing Organization: Olney Central College

Principal Investigator(s): Dr. John Evans
Olney Central College
Route 3
Olney, IL 62450
(618) 395-4351

Project Location: Olney, IL

Sponsoring Organizations: Illinois Department of Energy and Natural Resources
Olney Central College

Project Summary

The Olney Central College project staff have built a solar-assisted space heating and domestic hot water system to supply heat to the Applied Technologies Building located on the campus. It will be used as a practical teaching aid. The students enrolled in the energy technology programs have been doing the actual construction and testing of the system.

The solar system is an active liquid system consisting of 54 ground-mounted collectors and one 2,300 gallon storage tank. The storage tank will be the system's holding area for reserve solar heat. A central control system will provide heat to any area which electrically signals a need.

Heated transfer fluid (a propylene glycol solution) is circulated through a liquid-to-air heat exchanger. The air is then mechanically blown through the coils to the building duct work. A domestic hot water pre-heat coil is located near the top of the storage tank.

It is expected that the solar system will meet 60 percent of the annual heating load for the building.

A number of BTU meters are being used to monitor the performance of the system.

Projected Completion Date

June 30, 1985

Title: Sterling Park District Solar Hot Water Heating Project

Performing Organization:	Sterling Park District P.O. Box 692 Sterling, Illinois 61081
Principal Investigator(s):	Frank Duis, Director P.O. Box 692 Sterling, Illinois 61081 (815) 625-1265
Sponsoring Organizations:	Illinois Department of Energy and Natural Resources Midwest Appropriate Technology Small Grants Program, U.S. Department of Energy
Project Location:	Sterling Park District Recreation Center 211 E. St. Mary's Road Sterling, Illinois 61081

Project Summary

The goal of the entire project is to illustrate the effectiveness of a trickle-type solar collection system retrofitted to an existing corten mansard roof assembly on the Sterling Park District Recreation Center. The solar system heats the twin swimming pool complex and also supplies heated shower water for the building. This project will demonstrate the effectiveness of solar energy in this application through computerized data acquisition and analysis and will hopefully encourage other solar applications to new or retrofitted buildings.

The Sterling Park District Recreation Center possesses a corten steel mansard roof 243 feet long and 17-1/2 feet high which is ideal for solar collection. Two hundred sixteen feet of the south mansard roof have been covered with 110 - 4 ft. x 7 ft. double-faced collectors using filon and tedlar as the plate.

The Sterling Park District Recreation Center Solar Hot Water Heating System is comprised of four pumps plus a Westinghouse templifier heat pump with a capacity of 216,000 Btu per hour. This liquid-to-liquid heat pump is actually an absorption chiller which returns water to the twin pool complex and shower room facilities.

The savings on the project have been established at 89 therms a day from the 189 therms now being expended for heat energy. The net cost reduction in the Recreation Center's heating bill will be in the neighborhood of $11,000 a year. The building's backup to the solar collection system is a natural gas hot water boiler.

Projected Completion Date

The project was completed on June 19, 1982, at which time officials of the Illinois Department of Energy and Natural Resources celebrated the completion with an open house held at the center. Monitoring will continue through June, 1984.

Related Publications

Article and pictures on the project may be found in the May/June 1982 Volume 13, Number 3, issue of Illinois Parks and Recreation Magazine.

SOLAR HEATING AND COOLING: SEASONAL STORAGE

Title: Heat Extraction from Solar Ponds for Agricultural Applications

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Drs. Y.S. Sha and J.R. Hull
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
312/972-5899

Sponsoring Organizations: Illinois Department of Energy and Natural Resources

Project Location: Argonne National Laboratory

Project Summary

Argonne National Laboratory (ANL) proposes to study the extraction of heat stored in salt gradient solar ponds for various agricultural applications including crop drying, shelter heating and space heat. An existing salt gradient solar pond at ANL will be used to study two different techniques of heat extraction.

The first technique will use a plastic heat exchanger submerged in the solar pond. Air will be blown through the exchanger to pick up heat from the hot brine. The second technique pumps the hot brine to a finned-tube heat exchanger external to the solar pond. In this case, special flow distributors must be installed in the pond to minimize the disturbance of the salt gradient.

The effect of heat extraction on the stability of the gradient zone (which is vital to the successful operation of solar ponds) will be investigated by simultaneously measuring the temperature and concentration distributions in the pond during heat extraction. Other parameters (such as insolation, storage zone temperature variations) which are important in determining the overall pond performance will also be monitored continously.

The finned-tube heat exchanger is likely to be more effective than the submerged plastic heat exchanger as far as heat extraction is concerned, but, it is also likely to be considerably more expensive. By testing the two heat extraction systems using the ANL salt gradient solar pond, the cost effectiveness of these two systems can be determined.

The pond performance data obtained from the proposed project is valuable for the design of future solar ponds in the state of Illinois for agricultural as well as industrial applications.

Projected Completion Date

December 1984

Related Publications

None

Title: Salt-Gradient Solar Pond Research

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Dr. J.R. Hull (312) 972-8580
Dr. W.T. Sha (312) 972-5910
Dr. W.W. Schertz (312) 972-6230
Argonne National Laboratory
Argonne, IL 60439

Sponsoring Organization: Argonne National Laboratory

Project Location: Argonne, IL

Project Summary

A salt-gradient solar pond combines the collection and the storage of solar energy into one single operation. Solar radiation is absorbed and stored in the water at the lower levels of the pond. The water temperature at the lower levels of the pond can be as high as 70-90°C (160-194°F), while the surface temperature remains very close to the ambient air temperature. Convection is prevented by establishing a salt-gradient in the pond such that the salt concentration varies from zero at the surface to 20 percent at the bottom of the pond. As a result of the presence of the salt-gradient, the water at the lower levels of the pond is denser than that near the surface, thus preventing the hotter fluid at the lower levels from moving upward. The concept of collecting and storing solar energy by means of salt-gradient solar ponds was derived from studies of various natural lakes that had a salt concentration gradient. A salt-gradient solar pond normally consists of three zones; a thin convective zone at the surface, a non-convective gradient zone that provides thermal insulation in the middle, and a convective storage zone at the bottom. The pond collects and stores solar energy all year round and the available thermal energy in the pond can be extracted via a heat exchanger for various uses.

The ANL Research Solar Pond constructed in 1980 is 180 ft. x 80 ft. at the top with tapered sides and a depth of approximately 12 feet. It contains approximately 800,000 gallons of water and 700 tons of salt. A plastic liner is used to prevent leakage of the salt water into the surrounding ground. In the course of a year, the pond can provide approximately 10^9 Btu (2.9×10^5 Kwh) of thermal energy. A continuing research program on solar pond technology centers around the Research Solar Pond.

The solar pond provides the potential of low-cost solar energy collection and long-term storage of low-temperature heat. It is relatively easy to operate and needs little maintenance. A current estimate of the cost of heating using the solar pond is approximately 1.86 cents per Kwh, which is competitive with heating by fuel oil. With the increasing cost of fuel oil, the use of solar ponds will become more attractive.

Solar ponds have a wide range of potential applications including residential, industrial and agricultural. They can be used for water heating, space heating and cooling for residential and commercial buildings. Industrial applications include water and air heating for process and food industries. Crop drying, shelter heating and alcohol production are potential candidates for agricultural applications.

Projected Completion Date

Ongoing

Related Publications

Cha, Y.S., W.T. Sha and J.R. Hull. "Design, construction, and initial operation of the ANL research salt gradient solar pond," ANL-81-55 (in press).

Cha, Y.S., W.T. Sha and W.W. Schertz. "Modelling of surface convective layer of salt gradient solar ponds", Proceedings of the 1981 IECEC, Atlanta, Georgia, August 11-14, 1981.

Lin, E.I.H., W.T. Sha and S.L. Soo. "Technical and economic feasibility of solar ponds in large scale agricultural applications," Proc. of the 2nd Annual System Simulations and Economics Analysis Conference, San Diego, California, January 1980.

Hull, J.R., et. al. "Solar pond salt gradient instability prediction by means of a thermo-hydraulic computer code", Proc. 1981 AS/ISES, Philadelphia, May 1981.

Hull, J.R., et al. "Calculated dependence of ground losses upon solar pond size and perimeter insulation," to be presented at the ISES Conference, Brighton, England, August 1981.

Hull, J.R. "Calculation of solar pond thermal efficiency with a diffusely reflecting bottom." Submitted to Solar Energy, March 1981.

Cha, Y.S., W.T. Sha and S.L. Soo. "Effects of friction and extraction on the stability of solar ponds", to be presented at the 1981 ASME Winter Annual Meeting in Washington, DC, November 1981.

Title: Seasonal Ice Storage

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Anthony J. Gorski, P.E.
William W. Schertz, P.E.
9700 S. Cass Ave.
Argonne, IL 60439 (312) 972-6237

Sponsoring Organizations: U.S. Department of Energy
(Battelle, Pacific Northwest Laboratories)

Project Location: Argonne, IL

Project Summary

The Argonne Ice Storage and Test Facility (AISTF) is situated next to the Solar Collector Testing Station at the Argonne National Laboratory, approximately 35 miles southwest of the City of Chicago. The AISTF is used to test and evaluate ice-freezing heat pipes during the winter for use in summer cooling applications. The AISTF consists of a thermally insulated concrete tank containing 20,000 gallons of water, covered by a wooden shelter structure used to mount heat pipe components. During the winter months a variety of ice growing heat pipes installed in the tank can be monitored for performance.

During the winter of 1981-1982, two general types of heat pipes were tested in the AISTF. The first type consisted of a Roll-Bond™ condenser unit coupled to a four fin Roll-Bond™ evaporator unit. Three of these entered the winter season with condenser units mounted on the east and west roof sections and the north wall of the tank shelter. Another type heat pipe consisted of a large copper coil evaporator unit coupled to a Roll-Bond™ condenser unit mounted on the west roof of the tank shelter. Both types of heat pipes were filled with 5 lbs R12 refrigerent.

Winter results proved to be most interesting and in some cases quite unexpected:

1. All heat pipes grew ice in large amounts. By March 31, 1982, the four still working heat pipes had grown some 36,000 lbs of ice. Heat Pipe No. 2 on the north wall unit was damaged in attempting to manually remove ice.

2. In the Roll-Bond™ design, uniform ice growth was obtained only after replumbing such that condensate liquid return was to the lower end of the evaporator plates.

3. Due to the insulation characteristics of the tank, thermal inversion (0°C top, 4°C bottom) disappeared during the winter with the tank reaching a uniform 0°C throughout.

4. Ice release from the Roll-Bond™ design was observed only during the initial weeks of the season when ice thickness was 8 cm or less and the tank exhibited temperature inversion.

5. With the combination of several cold days and uniform tank temperatures, ice locked on to all Roll-Bond™ units forming ice "foot balls" some 2m (7 ft) high and 1.7m (5.5 ft) wide.

6. The coil evaporator unit proved to be high in thermal performance. This configuration may well have real potential in a total system configuration.

Experimental results will be shown, and a detailed outline of future work in the AISTF presented.

Projected Completion Date

Continuing

Related Publications

Gorski, A., et. al. "Long-term ice storage for cooling applications using passive freezing techniques", Proceedings of the Fourth National Passive Solar Conference, October 3-5, 1979, Kansas City, Missouri, p. 462.

Gorski, A., et. al. "Cooling by means of passively grown ice", American Section of ISES Solar Rising Conference, Philadelphia Civic Center, May 26-30, 1981, paper no. 574.

Title: The Development of a Naturally Frozen Annual Storage Ice System for Air Conditioning

Performing Organization:	Department of Industrial Technology Illinois State University
Principal Investigator(s):	Dr. C.E. Francis Dept. of Industrial Technology Illinois State University Normal, IL 61761
Sponsoring Organization:	IL Department of Energy and Natural Resources
Project Location:	Normal, Illinois

Project Summary

The purpose of the ISU Department of Industrial Technology project is to develop a cost-effective solar air conditioning system. The proposed hybrid cooling technique will be applicable to residential and commercial installations in regions which have sufficiently cold winters such as the State of Illinois.

It is proposed to design, construct, test and evaluate a full-sized (67 ton-day) naturally frozen annual ice storage air conditioning system. The system consists of three heat exchangers, a moderately sized storage mass and a small circulating pump. The storage mass will be contained in an evacuated pit lined with a polyethylene pool liner, then covered with soil, insulation and more soil. A small circulating pump will force propylene glycol through the heat exchanger, either freezing the storage mass or removing stored coldness from the mass and transferring it to the building to be cooled.

The system will provide complete residential air conditioning and will require no back-up system. Annual cost of operation is predicted to be less than 1/10 that of conventional air conditioning. The proposed technique does not require large areas of solar collectors or an expensive mechanical chiller unit. The basic idea is to use the normal cold temperatures during winter to generate a large mass of ice or frozen earth. This stored volume of cold energy is then used during summer months for air conditioning. It has been shown that if such a system can be built for \$6,000 to \$9,000, it will not only be competitive with solar AC, but also with conventional AC units now being used in Illinois.

Work being performed at Argonne National Laboratory will serve as a basis for this project. Instead of utilizing specialized components, the proposed system will use only components which are readily available from commercial sources. The system has the advantages of simple construction, low maintenance and automatic operation.

Each pound of ice grown is equivalent to 144 Btus of cooling energy. A cube of ice 15 feet^3 is equivalent to approximately 67 days, 24 hours a day. This is adequate to cool an average well insulated residence in Illinois. The storage mass will be contained in an evacuated pit 15' x 40' x 12' deep with sloped side, lined with an inexpensive double layer polyethylene pool liner. The storage mass will consist of water-saturated earth. Above the saturated earth will be dry earth, styrofoam insulation and more earth. A lawn, crawl space or garden shed may be placed on top if desired.

The thermal mass heat exchanger will consist of 3,200 feet of 1/2" polyethylene tubing strategically distributed throughout the mass and terminated into appropriate headers. A small circulating pump will be used to pump propylene glycol through the heat exchangers. One construction feature is that all piping connectors will be permanently accessible for inspection and maintenance should it become necessary.

The system is predicted to cost from $3,500 to $4,000. Without taking annual energy inflation into consideration, payback would occur in 16 years. With energy inflation and a possible 40 percent tax credit, payback would occur in less than seven years and a do-it-yourself installation would pay back in less than five years.

The monitoring instrumentation for this project consists of standard SERI/DOE Class-B instrumentation package manufactured by Aeolian-Kinetics, Inc. Computer data analysis will be performed by the existing computer at the Department of Industrial Technology. The measurements to be taken will consist of various temperatures throughout the frozen mass, instantaneous and total solar insolation, wind speed and pump and blower on-off operations.

Projected Completion Date

October 1984

Related Publications

None

SOLAR HEATING AND COOLING: SOLAR COLLECTOR TECHNOLOGY

Title: Fundamentals and Techniques of Nonimaging Optics for Solar Energy Concentration

Performing Organization: The University of Chicago
Solar Energy Group

Principal Investigator(s): Prof. Roland Winston (312) 962-7756

Dr. Joseph J. O'Gallagher (312) 962-7757

Sponsoring Organization: The U.S. Department of Energy
Office of Basic Energy Sciences
Division of Mathematical, Geophysical
and Engineering Sciences under
DOE Contract: DE-AC02-80ER10575

Project Location: The University of Chicago
5630 South Ellis Avenue
Chicago, IL 60637

Project Summary

Nonimaging optics is a new research area developed in the last 10 to 15 years which describes how to design systems which attain the maximum possible concentration for a given field of view. In solar energy this has led to the development of concentrators which do not need to track the diurnal motion of the sun and also to tracking concentrators with relaxed tolerances. This is the second year in a formal three year program whose basic objectives are the further development of the theoretical formulation of nonimaging optical principles and the investigation of practical questions having to do with the implementation of newly developed designs for solar and other applications. The theoretical formalism established during earlier programs has been extended so that one can now describe all forms of "ideal" concentrators known at present in terms of the lines of flow of a vector field. An extension to the physical optics domain based on new theories of radiometry in partially coherent light has been initiated and appears more promising. Linear concentrator designs to reduce "gap losses" for tubular absorbers have been analyzed in detail. Studies of the performance of Fresnel lenses and less conventional diffractive components (i.e., holograms) have been initiated. A ray trace optimization of two second stage concentrators (the CEC and the "trumpet") has been carried out. Studies of nonimaging secondary concentrator configurations for photovoltaic applications with particular emphasis on solid refracting and totally internally reflecting elements have recently been undertaken.

Projected Completion Date

December 31, 1986

Related Publications

Welford, W.T. and R. Winston, The Optics of Nonimaging Concentrators, Academic Press, New York, 1978.

Title: Nonimaging Solar Energy Concentrators

Performing Organization: University of Chicago Solar Energy Group

Principal Investigator(s): Prof. Roland Winston
5630 South Ellis Avenue
Chicago, Illinois (312) 962-7756

Sponsoring Organization: U.S. Department of Energy

Project Location: The University of Chicago, Enrico Fermi Institute
5630 South Ellis Avenue
Chicago, Illinois 60637

Project Summary

The objective of this research program is to design, fabricate and test nonimaging solar energy collectors that concentrate sunlight by the maximum amount allowed by the second law of thermodynamics. For concentration ratios up to 10, no tracking during the day is required. Nonimaging concentrators can be designed for a variety of tasks: heating and cooling of buildings, industrial process heat (IPH) and electric power generation from photovoltaics. For thermal applications, the expected operating temperatures range from 200°C for totally stationary collectors to 300°C for seasonally adjustable collectors, to over 400°C for simple tracking systems.

Facilities include a roof-top test station with a computerized data acquisition, analysis, and storage system and a 400°C temperature capability. A computer simulation of long-term collector performance has also been developed. The group designed and supplied nonimaging solar collectors for a Bureau of Indian Affairs school at Bread Springs, New Mexico and is assisting in data collection and performance analysis.

Our current projects include a collaboration with GTE-Sylvania in Waltham, Massachusetts, to develop a completely stationary, high-temperature solar collector. The collector's performance is comparable to the best commercial tracking parabolic troughs, without the need for tracking the sun. This high conversion efficiency is the result of a novel combination of three recent advances in collector technology: 1) nonimaging concentration, 2) "selective" absorption and 3) conduction and convection suppression through the use of a vacuum environment. It is believed that this new solar collector could be mass produced due to the similarity of many of its processes and components to those of a fluorescent light.

A continuing theoretical program examines unexplored areas in the field of nonimaging optics, with particular emphasis on questions relevant to the efficient collection and concentration of solar radiation.

Projected Completion Date

Ongoing

Related Publications

Chicago Tribune, Sunday, September 20, 1981, Section 1, p. 16

"Concentrating collector yields high temperature without tracking sun," *Popular Science*, July 1982, p. 30.

Winston, R. "Principles of solar concentrators of a novel design," *Solar Energy* 16:89-95, 1974.

O'Gallagher, J.J., et al. "A new evacuated CPC collector tube," submitted to *Solar Energy*, 1982.

Title: Optimized Design for Integrated CPC Tubes and Arrays

Performing Organization: The University of Chicago,
Solar Energy Group

Principal Investigator(s): Prof. Roland Winston (312) 962-7756

Dr. Joseph J. O'Gallagher (312) 962-7757

Sponsoring Organization: The U.S. Department of Energy
Office of Conservation and Solar
Applications under
DOE Contract: DE-AC03-82SF11655

Project Location: The University of Chicago
5630 South Ellis Avenue
Chicago, IL 60637

Project Summary

The integrated Compound Parabolic Concentrator vacuum tube has achieved a substantial improvement in performance, temperature range, lifetime and system simplicity relative to other contemporary solar collectors.[1] This was accomplished by incorporating the nonimaging CPC-type concentrator profile directly into the vacuum enclosure by shaping the cylindrical glass tube which forms the outer envelope. A proof of concept development phase has been completed which eliminated questions as to the concept's technical feasibility in both the areas of 1) integrity of mechanical structure and tolerances and 2) thermal performance. Over 80 prototype tubes were fabricated and a panel of 45 has been under test for more than one year. The measured efficiency is dramatically improved above contemporary evacuated tube collectors (for example, the peak efficiency is 55 percent relative to beam at 200°C) based on a somewhat conservative design. Thus the technical feasibility of a high-performance fully stationary solar collector for temperatures in the range 100°C-300°C has been established. Further improvements are expected as the design evolves.

The present project utilizes the results of recent research to optimize the tube design and address some of the technical problems associated with the deployment of large arrays of such tubes. Particular questions to be investigated include methods for improving the detailed design of the tube itself such as a) possible refinement of the optical design to incorporate recent solutions to reduce the so-called "gap-loss," b) a determination of the optimum structural configuration and size, and c) selection of improved materials for the selective coating and reflector surfaces. In addition, methods for reducing parasitic thermal and pumping power losses in large arrays of tubes are being evaluated and important operational questions such as stagnation protection and temperature and flow control strategies are being developed. Examples of systems for specific end use applications are medium temperatures steam production and space cooling using either absorption type or Rankine cycle chillers.

Projected Completion Date

June 30, 1985

Related Publications

[1] O'Gallagher, J., K. Snail, R. Winston and S.C. Peek. "A new evacuated CPC collector tube," to be published in *Solar Energy*, 1982.

[2] O'Gallagher, J., K. Snail and R. Winston. "Performance testing of a panel of evacuated tubes with integrated CPC," presented at the 1982 Meeting of the American Solar Energy Society, Houston, Texas, 1982.

Title: Studies of Working Fluids for Low Gradient Thermal Cycles and Solar Energy Cooling and Heating Systems

Performing Organization:	University of Illinois at Chicago Department of Chemical Engineering
Principal Investigator(s):	G. Ali Mansoori Professor Chemical Engineering University of Illinois at Chicago Chicago, Illinois 60680 (312) 996-3424
Sponsoring Organizations:	Petrosol Energy Co. Dallo Solar Systems, Ltd. Argonne National Laboratory
Project Location:	University of Illinois at Chicago Department of Chemical Engineering

Project Summary

A. Study in characteristics of candidate fluid mixtures as working fluids for low gradient thermal cycles. Development of upper and lower bounds for efficiencies and performance of thermal cycles. Application of irreversible thermodynamics for analysis of heat transferring components.

B. Research and development work in solar energy utilization. Studies in the choice of working fluids for absorption cooling cycles. Design of integrated system for heating and cooling of buildings. Economic analysis of utilization of solar heating and cooling systems. Laboratory studies in modification of existing absorption cooling cycles for use with solar-generated thermal energy.

C. Research, design, and feasibility studies in chemical storage systems, phase-change storage system. Seasonal energy conservation schemes. Design of water pumping systems from low to high elevations through solar energy. Solar water desalination. Use of ocean thermal gradient for water desalination purposes.

Related Publications

Mansoori, G.A. and V. Patel. "Thermodynamic basis for the choice of working fluids for solar absorption cooling cycles", Solar Energy Journal, 22: 483-491, 1979.

Mansoori, G.A. "Prospects for solar energy utilization", Iranian J. Science and Tech., 5: 55-73, 1976.

Gabor, J.D., L. Baker, J.C. Cassulo and G.A. Mansoori. "Heat transfer from heat generating boiling pools", Chemical Engineering Progress, 73: 78-85, 1977.

Gomez, A.L. and G.A. Mansoori. "Thermodynamic efficiencies revisited (upper and lower bounds to the efficiencies and coefficient of performance based on the second law of thermodynamic)", Proceedings of the 2nd World Congress of Chemical Engineering, II: 241-248, 1981.

Gomez, A.L. and G.A. Mansoori. "Thermodynamic equation of state approach for the choice of working fluids of absorption cooling cycles," Solar Energy Journal. (to appear 1983).

SOLAR PHOTOVOLTAICS

Title: Thin Films

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Dr. Ivan K. Schuller
Solid State Science Division
Argonne National Laboratory
Argonne, IL 60439 (312) 972-5469

Sponsoring Organizations: Department of Energy
Office of Naval Research

Project Location: Argonne, IL 60439

Project Summary

This research project deals with the development of new materials, using thin film techniques. In particular, we prepare alternating layers of very thin (< 100 A) metals to engineer novel, desirable properties which are not characteristic of the individual constituents. Several combinations have been found that do not interdiffuse and form alloys. Interesting physical phenomena such as metal-insulator transition, phonon softening and unusual magnetic properties have been engineered. A material for metal film resistors with high specific resistivity (150 microhm-cm) and low temperature coefficient of resistivity (< 10 ppm/°K) is in the patenting process. A material for superconducting magnet wire with critical fields three times higher than conventional material has also been developed. These basic research developments have possible applications in magnets for fusion conversion.

The structure of hydrogenated amorphous silicon has also been determined for the first time, using neutron scattering techniques. Three samples (5 g/eo) were prepared using high rate magnetron sputtering techniques. These materials have potential for photovoltaic and photothermal conversion of sunlight into electricity.

Projected Completion Date

Ongoing

Related Publications

Schuller, Ivan K., et al. "Transport properties of the composition modulated alloy Cu/Ni", Modulated Structures-1979, AIP Conference Proc. 53:417, 1979.

Schuller, Ivan K. and C.M. Falco. "Layered ultrathin coherent structures (LUCS)", Inhomogeneous Superconductors-1979, AIP Conf. Proc. 58:197, 1979.

Schuller, Ivan K. "A new class of layered materials," Phys. Rev. Letters 44:1597, 1980.

Zheng, J.Q., C.M. Falco, J.B. Ketterson and Ivan K. Schuller. "Magnetization of compositionally modulated CuNi films," Appl. Phys. Letters 38:424, 1981.

Postol, T., C.M. Falco, R.T. Kampwirth, Ivan K. Schuller and W.B. Yelon. "The structure of amorphous silicon and silicon hybrides," Phys. Rev. Letters 45:648, 1980.

Meyer, K.E., G.P. Felcher, S.K. Sinha and Ivan K. Schuller. "Models of diffraction from layered ultrathin coherent structures," J. Appl. Phys. 52:6608, 1981.

Meyer, K.E., Ivan K. Schuller and C.M. Falco. "Thermalization of sputtered atoms," J. Cappl. Phys. 52:6608, 1981.

Schuller, Ivan K. and C.M. Falco. "Metallic superlattices," Chapter in Microstructure Science and Engineering/VLSI, ed. N.G. Einspruch, Academic Press, New York (in press).

Zheng, J.Q., J.B. Ketterson, C.M. Falco and Ivan K. Schuller. "Superconducting and transport properties of NbTi layered metals," Physica B & C 108:945, 1981.

Schuller, Ivan K. and C.M. Falco. "Structure and physical properties of sputtered metallic superlattice," Surf. Sci. 113:443, 1982 and Chapter in Electronic Properties of Two-Dimensional Systems, ed. Frank Stern, North-Holland, Amsterdam, 1982.

Kueny, A., M. Grimsditch, K. Miyano, I. Banerjee, C.M. Falco and Ivan K. Schuller. "Anomalous behavior of surface acoustic waves in Cu/Nb superlattices," Phys. Rev. Letters 48:166, 1982.

Zheng, J.Q., J.B. Ketterson, C.M. Falso and Ivan K. Schuller. "The magnetization and Curie temperature of compositionally modulated Cu/Ni films," J. Appl. Phys. 53:3150, 1982.

Schuller, Ivan K. and C.M. Falco. "Superconductivity and magnetism in metallic superlattices," Solid State Commun. 41:805, 1982.

Falco, C.M. and Ivan K. Schuller. "Artificial metallic superlattices," Chapter in Novel Materials and Techniques in Condensed Matter ed. G.W. Crabtree and P.D. Vashishta, American Elsevier, New York, 1982.

Yang, Q.S., C.M. Falco and Ivan K. Schuller. "Tunneling studies of a metallic superlattice," (in preparation).

Werner, T.R., I. Banerjee, C.M. Falco and Ivan K. Schuller. "Localization in three dimensional metals," Phys. Rev. B. (in press).

Khan, M.R., Ivan K. Schuller and C.M. Falco. "Sputter epitaxy of Ag and Ni films," Phys. Stat. Solidi (in press).

Title: Optimized Hybrid Collector for Total Solar Cogeneration (TSC)

Performing Organization:	Western Illinois University Department of Physics
Principal Investigator(s):	Dr. David E. Soule Department of Physics Western Illinois University Macomb, IL 61455 (309) 298-1340 or 1596
Sponsoring Organization:	IL Department of Energy & Natural Resources
Project Location:	Macomb, Illinois

Project Summary

The objective of this program is to evaluate a new approach to hybrid solar collection--total solar cogeneration (TSC). This method optimizes both the input solar conversion and the output conservation of power by,

a. Conversion of total incident solar spectrum (0.3 - 2.6 m),

b. Cogeneration of total output to multiple useful forms of energy (electricity, high-temperature heat and low-temperature heat).

The TSC hybrid collector system combines in one unit the features of a well cooled photovoltaic solar cell with those of an evacuated-tube high-temperature absorber. The receiver is incorporated with a parabolic trough mirror system with 50-100 X concentration. A prototype TSC collector is proposed for test studies on a flat-roof industrially simulated site. It will be capable of direct cogeneration of electricity, high-grade heat up to 400°C and low-grade heat at 70°C. The efficiency of the TSC system (preliminary estimate of 60 percent) can be simultaneously optimized both thermodynamically and spectrally for different cogeneration modes. For example, the high-temperature heat may be used directly for industrial process heat, the low-temperature heat for space heating and the electricity for multiple purposes. In practice, arrays of these TSC collectors can be oriented on individual industrial or commercial flat roof-tops to provide self-contained power for flexible applications.

The overall program of investigation also includes:

a. Installation of a roof-top solar test station at Western Illinois University (Macomb, IL, 40°N) for year-round computer monitoring and statistical analyses.

b. Computer simulation model studies to optimize the efficiency for photovoltaic-photothermal solar conversion.

c. Optical and thermal materials testing, proceeding from a current program on thin-film spectral profile tailoring and thermal stability.

Projected Completion Date

June 1985

Related Publications

Soule, D. E., J. H. Schnitzmeyer and W. R. McKie, "Fermi function model absorption profile for solar-thermal conversion," Proc. AS-ISES/SES, Winnipeg, Canada, 5: 310-322, 1976.

Soule, D. E. and D. W. Smith, Infrared Spectral Emittance Profiles of Spectrally Selective Solar Absorbing Layers at Elevated Temperatures, Appl. Optice 16: 2818-2821, 1977.

McMillan, J. A., D. E. Soule, R. T. Kampwirth and E. M. Peterson, "The role of spectral selectivity in hybrid solar energy conversion," Proc. AS-ISES, Denver, CO, 2.2: 300-303, 1978.

Soule, D. E., "Directional absorptance spectrocalorimetric measurement and spectral profile parametrization of solar absorbers at elevated temperatures," Proc. Absorber Surfaces for Solar Receivers, Boulder, CO, SERI-TP-49-182, 1979, pp. 173-182.

Soule, D. E. and G. T. Reedy, "Infrared spectra of the hydrogenated amorphous silicon layers on metallic substrates of solar absorbers," Thin Solid Films 63: 175-181, 1979.

SOLAR THERMAL AND ADVANCED TECHNOLOGIES

Title: Liquid-Metal MHD

Performing Organization: Argonne National Laboratory

Principal Investigator(s):
Michael Petrick
Argonne National Laboratory
Argonne, IL 60439 (312) 972-5960

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3920 Lake Shore Drive
Chicago, IL 60613 (312) 327-9188 or
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Sponsoring Organization:
U.S. Department of Energy
Solmecs Corporation (Israel)

Project Location:
Argonne National Laboratory
Argonne, IL 60439

Project Summary

The two-phase-generator, liquid-metal magnetohydrodynamic (LMMHD) energy-conversion concept was initially developed at Argonne National Laboratory. Its use of two working fluids, a thermodynamic fluid (gas or vapor) and an electrodynamic fluid (liquid metal) to provide the electrical conductivity, gives LMMHD great versatility in coupling to different heatsource temperatures. A Rankine (vapor) cycle can be used at the lower temperatures characteristic of waste heat recovery or other types of solar collectors.

The reasons solar-powered LMMHD appears attractive are:

1. the potential for a conversion efficiency higher than alternative conversion systems or both electricity and high-temperature process heat (cogeneration); and

2. efficiency and cost are almost independent of size.

The major results of solar LMMHD performance studies are:

1. the LMMHD Rankine cycle has higher efficiency than other Rankine cycles without process heat, or the same efficiency with process heat as the other cycles have without process heat; and

2. the LMMHD Brayton cycle has an efficiency comparable to or higher than advanced Stirling engines and is very attractive for cogeneration applications.

Currently, analytical and experimental studies for low-temperature applications are being undertaken in cooperation with the Ben-Gurion University of the Negev in Israel and Solmecs Corporation (Israel). A study on high-temperature solar systems is in progress cooperatively with HMJ Corporation.

Projected Completion Date

Ongoing

Related Publications

Pierson, E.S., H. Branover, G. Fabris and C.B. Reed. "Solar powered liquid-metal MHD power systems," Mechanical Engineering 102:32-37, October 1980.

Pierson, E.S. "New liquid-metal MHD concepts for solar and coal," Proc. of the American Power Conference, Chicago, April 1980.

Pierson, E.S. and H. Herman. "Solar-powered liquid-metal MHD performance and cost studies," Proc. of the Third Beer-Sheva Seminar on MHD-Flows and Turbulence, Beer-Sheva, Israel, March 1981.

Geyer, H.K. and E.S. Pierson. "Solar liquid-metal MHD performance predictions," Proc. of the 20th Symposium on Eng. Aspects of MHD, Univ. of California, Irvine, California, June 1982.

Branover, H. et al, "Development of a Low Temperature Liquid-Metal MHD Small Scale Pilot Plant," Proc. of the 21st Symposium on Eng. Aspects of MHD, Argonne National Laboratory, Argonne, Illinois, June 1983.

Title: Bioengineering of Man-Made Photosynthetic Membranes

Performing Organization: University of Illinois

Principal Investigator(s): Constantin A. Rebeiz
Laboratory of Plant Pigment
Biochemistry and Photobiology
1103 West Dorner Drive
Urbana, IL 61801

Sponsoring Organizations: N/A

Project Location: Urbana, IL

Project Summary

Our research effort has focused on the bioengineering of man-made photosynthetic membranes which are much more efficient in converting solar energy, CO_2 and H_2 into chemical energy than the natural green membranes of plants. So far this research has involved fundamental investigations of the biosynthesis and chemical structure of several newly discovered chlorophyll chemical species and the development of cell-free systems capable of greening *in vitro* at rates higher than *in vivo*.

Projected Completion Date

N/A

Related Publication

Rebeiz, Constantin A. "Chlorophyll: anatomy of a discovery." *Chemtech* 12:52-63, 1982.

Title: An Experimental Investigation of Convective Heat Losses from Solar Energy Receivers

Performing Organization: Department of Mechanical Engineering
University of Illinois at Urbana-Champaign

Principal Investigator(s): Professor A.M. Clausing
Department of Mechanical and Industrial Engineering
College of Engineering
144 Mechanical Engineering Building
1206 West Green Street
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Sponsoring Organizations: Sandia National Laboratory/DOE
University of Illinois
Other Support is Pending

Project Location: University of Illinois at Urbana-Champaign

Project Summary

A cryogenic, recirculating wind tunnel has been constructed for the study of free, forced and combined convection heat transfer. The operating ambient temperature of approximately 80°K results in large increases in the Reynolds number and spectacular increases in the Grashof number over those obtainable in room temperature facilities. A further advantage of the cryogenic temperature level is the virtual elimination of radiative heat transfer. Hence, the facility provides a means of experimentally determining the convective heat exchange from large objects in cases where both inertia and buoyant forces are significant. The tunnel has a test section of 0.6 m by 1.2 m and a design velocity of 9 m/sec. It is currently being used to study: (1) combined convection heat transfer from the large solar receivers which are being proposed for the central receiver ("power tower") concept; (2) the influences of property variation in free, forced and combined convection; and (3) the influence of the aspect ratio on convective heat transfer from cylinders.

Projected Completion Date

1985

Related Publications

Clausing, A.M. "New natural convection correlations for isothermal vertical surfaces," accepted for publication by ASME.

Clausing, A.M., R.J. Skarda and K.C. Wagner, "Prediction of convective losses from external, cylindrical solar receivers," Proc., 1982 Annual AS/ISES Meeting, Houston, Texas, 5(1):299-304, 1982.

Clausing, A.M. "Advantages of a cryogenic environment for experimental investigations of convective heat transfer," to be published in IJHMT, 1982.

Clausing, A.M. and S.N. Kempka, "The influences of property variations on natural convection from vertical surfaces," ASME J. of Heat Transfer, 103(4):609-612, 1981.

Clausing, A.M. "An experimental investigation of convective losses from solar receivers," Proc. 1981 DOE/SERI/SNLL Symp. on Convective Losses from Solar Receivers, Sandia Laboratories Report SAND81-8014, 1981, pp. 51-60.

Clausing, A.M., G. Clark and M. Mueller. "The cryogenic heat transfer tunnel--a new tool for convective research," Modeling, Simulation, Testing, and Measurements in Solar Energy Systems, ASME, New York, 1978, pp. 73-78.

GEOTHERMAL AND OCEAN THERMAL

Title: Low Temperature Resource District Heating Project

Performing Organization: Argonne National Laboratory

Principal Investigator(s): D. Ramswami, M.J. Bernard III, and
A.S. Kennedy
Center for Transportation & Urban Research
Energy and Environmental Systems Division
Argonne National Laboratory
Mail Stop 362-2B
Argonne, Illinois 60439 (312) 972-6380
(312) 972-3738
(312) 972-3995

Sponsoring Organizations: U.S. DOE
Office of Conservation & Renewable Energy
Office of Building Energy Research & Development

Project Location: Argonne National Laboratory and
Scranton, Pennsylvania

Project Summary

Vast low temperature energy resources remain utilized. These can be used for space heating and cooling. One such low temperature resource and the initial research location is water at a temperature of 55°F through the year in the abandoned coal mines of Scranton, Pennsylvania. The objective of the ANL Project is to perform the research and development needed to pump the heat from/to water as a heat source/sink for space heating and cooling of large communities. The research and development includes in-situ testing of below-ground heat exchangers. The results are published in widely circulated reports. This work is very important to many communities because it facilitates the utilization of yet untapped energy capacity of below-ground waters.

Project Completion Date

Ongoing program

Related Publications

Bibliography available on request

Title: Ocean Thermal Energy Conversion (OTEC) Power Systems Development

Performing Organization: Argonne National Laboratory

Principal Investigator(s): A. Thomas and N.F. Sather
ANL
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Bldg. 362
Argonne, Illinois 60439 (312) 972-8071
(312) 972-3724

Sponsoring Organizations: Department of Energy
Conservation and Renewable Energy

Project Location: Argonne National Laboratory and
Seacoast Test Facility,
Keahole Point, Island of Hawaii

Project Summary

OTEC is a means for producing electrical power from the temperature difference between deep ocean water and the warm surface waters of tropical seas. The objective of the ANL program is to foster the development of power systems for OTEC plants. In particular, heat exchangers selected for their characteristics of high performance or low-cost fabrication potential are installed and tested in a 1-megawatt thermal test loop at the Laboratory. The results are analyzed and published in widely circulated reports. In addition to the testing work, analytical modeling of two-phase forced-convection flow in compact heat exchangers is conducted. Experimental research in biofouling, corrosion and biofouling control is carried out, primarily at the Seacoast Test Facility in Hawaii. Promising biocontrol techniques are selected and subjected to long-term testing in marine environments. This work is important because levels of biofouling which may be acceptable in conventional power plants are unacceptable for OTEC applications.

Projected Completion Date

Ongoing program

Related Publications

Bibliography available on request

Title: Dropwise Condensation on Electroplated Noble Metal Surfaces

Performing Organization: University of Illinois

Principal Investigator(s): James W. Westwater
Professor of Chemical Engineering
University of Illinois
Urbana, IL 61801
217-333-3634

Sponsoring Organizations: U.S. Department of Energy

Project Location: Urbana, Illinois

Project Summary

Dropwise condensation results in much higher heat transfer coefficients than with the common filmwise condensation. If dropwise condensation could be used in the enormous heat exchangers envisaged for ocean thermal energy conversion, the size and cost of these items would be reduced dramatically. This would result in a large conservation of valuable metals. Dropwise condensation is attractive for any heat exchanger which has good heat transfer characteristics on both the hot side and the cold side such as a condensing vapor on one side and a boiling liquid on the other. Traditional promoters used to achieve dropwise condensation are organic coatings. In every case these wash off and must be replenished. The present research is a study of permanent promoters such as electroplated layers of gold or silver. Important questions concern the proper thickness, the lifetime of the coating, and the details of the deposition.

Projected Completion Date

1985

Related Publications

Woodruff, D.W. "Steam condensation on various gold surfaces," Journal of Heat Transfer, 103:685-692, 1981.

"Gold surfaces for condensation heat transfer," Gold Bulletin, 14:95-101, 1981.

Woodruff, D.W. "Steam condensation on electroplated gold: effect of plating thickness," Intern. J. Heat Mass Transfer, 22:629-632, 1979.

"Condensation," Chapter in Heat Transfer in Energy Problems, eds. Tokuro Mizushina and Wen-Jei Yang, Hemisphere Pub. Co., 1982.

WIND ENERGY

Title: Illinois Solar Weather Study

Performing Organization: Water Survey Division
Department of Energy and Natural Resources

Principal Investigator(s): Richard G. Semonin
Illinois State Water Survey
Box 5050, Station A
Champaign, Illinois 61820 (217) 333-4967

Sponsoring Organization: Illinois Department of Energy and Natural Resources

Project Location: The entire state of Illinois

Project Summary

Development of the sites and implementation of sensing and recording equipment has continued to progress steadily. The six sites at Bondville/Champaign, Brownstown, DeKalb, Dixon Springs, Monmouth and Perry are now fully operational in all respects, and data acquisition from each of them has been very satisfactory. Table 1 provides the initial dates of the recording of solar and wind data for each of these sites. Additionally, solar and wind data are being obtained from Argonne National Laboratory at Lemont to supplement our network data.

The worst problems at these six sites have resulted from recorder failure and observer errors. Except at Monmouth, where extensive periods of both wind and solar data have been lost due to lightning-related failures of the recording equipment, only very isolated instances of in excess of two consecutive days of data have been lost at any site. The other main causes of data loss have been related to the icing/freezing of anemometers during/after ice storms, local power failures and attending observers failing to change recorder papers. Data loss could be decreased by the installation of additional lightning arrestors at each site, planned modifications to recorders to permit them to turn on automatically after power restoration following outages and further instruction of observers.

The four sites at Belleville, Freeport, Olney and Springfield are completed in all aspects except for the installation of the data acquisition systems. We are currently awaiting delivery of these units which are expected to become available to us over the next two months, and as they do, these four sites will immediately become operational. Four additional sites at Carbondale, Peoria, Rend Lake and St. Anne are in a stage of negotiation with respect to exact site locations, responsibilities and provision of approval by governing agencies. It is currently expected that in each case satisfactory solutions will be achieved.

We are now beginning to develop a sizable and useful data base in both solar and wind, and with a fairly good spatial resolution over the state. However, one other major problem is now emerging as the volume of incoming data increases; it is becoming increasingly difficult to key the data into the necessary computer files and to verify and screen them for potential problems as rapidly as they come in from the field. It is confidently expected that as we resolve our various teething problems, the other sites become operational and the data base develops, that we will be able to make positive contributions toward the evaluation of solar and wind as potential alternative energy strategies for Illinois.

TABLE 1: Onset months of acceptable data recording at the sites which are currently fully operational

Site	Solar	Wind
Bondville/Champaign	May 1981	February 1982
Brownstown	July 1981	June 1982
DeKalb	June 1981	May 1982
Dixon Springs	June 1981	May 1982
Monmouth	August 1981	May 1982
Perry	June 1981	April 1982

Projected Completion Date

Ongoing

Related Publications

Wendland, W.M. Illinois Wind Power Program. SWS Contract Report 266, Illinois State Water Survey, Champaign, 1981, 20 pp.

Hendrie, L.K. Illinois Solar Weather Program. SWS Contract Report 276, Illinois State Water Survey, Champaign, 1981, 40 pp.

Hendrie, L.K. Illinois Solar Weather Program. SWS Contract Report 304, Illinois State Water Survey, Champaign, 1983, 75 pp.

In addition to the above annual reports, quarterly data reports are in preparation and will be issued within three months of the end of each calendar quarter.

Title: Utilization of Nocturnal Wind Energy Maxima

Performing Organization:	University of Illinois at Urbana-Champaign Department of Aeronautical and Astronautical Engineering
Principal Investigator(s):	Charles E. Bond AAE Department University of Illinois 109 Transportation Building 104 S. Mathews Street Urbana, Illinois 61808 (217) 333-3739 or 367-8995
Sponsoring Organization:	University of Illinois
Project Location:	Central Illinois

Project Summary

This research comprises an analytical and experimental investigation of the significance of low-level nocturnal wind maxima for wind-energy conversion in the midwestern United States. The project includes direct measurements of the vertical profile (wind shear) of these increased winds, analytic assessment of their economic significance for large and small wind energy conversion systems, and the development of reliable, low-cost procedures and techniques for prospecting the wind shear by potential owners of wind energy systems.

Projected Completion Date

Ongoing

Related Publications

None to date

Title: A Cost-Effective Wind-Powered Electrical Energy Production System

Performing Organization: Windgen Ltd.

Principal Investigator(s): Sherman Ovelmen
Windgen Ltd.
1265 Countryside Drive
Elgin, IL 60120

Sponsoring Organization: None

Project Location: Elgin, Illinois

Project Summary

From 1977 to date two cost-effective wind-powered electrical energy production systems have been designed, built, installed and tested in the Elgin, Illinois area.

Both systems are mounted on a 46-foot triple-guyed, steel tube tower. Each system has a synchronous inverter electrical transversion system, sitka spruce fiberglass-covered rotor blade, and an aerodynamic method of controlling rate of yaw and rotor blade speed. Each system has a Georator alternator which is matched to the power production of the rotor blades.

The first wind turbine has an 18-foot diameter rotor blade and has been in continuous operation for more than two years. The second wind turbine has a 14-foot rotor blade and has been in continuous operation for about 1-1/2 years. Both turbine systems have functioned safely through wind, snow, ice and electrical storms.

The 14-foot system cost about $7,000 to build and install, and the 18-foot system cost about $12,500. Both systems should pay for themselves in energy savings in about five more years.

The wind turbine system with the rotor diameter of 14 feet has the following performance characteristics:

1) Start to turn wind speed = 8 mph
2) Start to produce electrical energy = 9 mph
3) Electrical power production at 14 mph wind speed = 800 watts
4) Electrical power production at 20 mph wind speed = 1,500 watts
5) Power production at average wind speed of 12.5 mph = 450 kwh/mo.

The wind turbine system with the rotor diameter of 18 feet has the following performance characteristics:

1) Start to turn wind speed = 8 mph
2) Start to produce electrical energy = 9 mph
3) Electrical power production at 14 mph wind speed = 1,200 watts
4) Electrical power production at 20 mph wind speed = 3,000 watts
5) Power production at average wind speed of 12.5 mph = 900 kwh/mo.

Projected Completion Date

Ongoing for monitoring and demonstration

Title: The Use of a Wind Turbine for Remote Pond Aeration

Performing Organization: Windgen Ltd.

Principal Investigator(s):
Sherman Ovelmen
Windgen Ltd.
1265 Countryside Drive
Elgin, IL 60120 (312) 742-5126

Tom Harder
Max McGraw Wildlife Foundation
P.O. Box 194
Dundee, IL 60118 (312) 741-8000

Sponsoring Organizations: Max McGraw Wildlife Foundation

Project Location: Dundee, IL

Project Summary

One of the problems with holding fish over winter in remote rearing ponds is the risk of losing all or part of the stock to winterkill. The Max McGraw Wildlife Foundation, Dundee, IL, has been investigating a wind-powered aeration system for several years, since seven of our rearing ponds are at remote sites.

Our needs were discussed with Sherman Ovelman of Windgen Ltd. He and several associates have been working on computer simulation designing of wind-turbine systems for the past five years.

Windgen designed a wind turbine for a 46-foot tower to be mounted at one of the highest points on the Foundation's property adjacent to three of our 1-acre rearing ponds. It has a 14-foot turbine blade made of laminated Sitka spruce, hand molded and fiberglassed. The turbine blade rotates a pulley at a 1:4.25 ratio which runs a 3 HP Gast, high volume, oiless rotary-vane compressor. A 3/4 inch reinforced neoprene rubber hose connects the compressor to the 3/4 inch semirigid pvc delivery line at the tower base. This pvc line runs approximately 150 feet and then splits off into two ponds. Aeration is effected by the use of 20 feet of Schramm bioweave™ diffusor hose in each pond.

The turbine is designed to begin pumping air in 8-10 mph winds and to gradually begin tipping out of the wind at 15-16 mph, while still aerating. Since the compressor is rated for intermittent use only at 15 psi, a 12 $ft.^2$ stabilizer blade was designed to allow the turbine to tip out of the wind completely in high winds. This blade will keep the turbine stable in 60+ mph winds.

At a yearly average wind speed of 14.3 mph, this Windgen unit is designed to pump 24 cfm at 5 psi. At average winter wind speeds of 17 mph, it should put out 26.5 cfm at 11.5 psi.

The original turbine/compressor unit worked all fall providing the two ponds with a good pre-winter supply of oxygen (13-16 mg/L).

In December, the original 3HP Gast rotary vane compressor was replaced with a Gast heavy-duty, spring-loaded compressor of the same HP. This was done after the turbine was found to have overpowered the original compressor, wore out two timing belts and cracked one of the compressors' vanes. At this time the turbine blades were shortened to 12 feet.

With the new turbine combination there was open water around the diffusor hoses for 11 of 22 observation dates in January. These ice-free areas varied in size from a 6-foot circle to an area 75' x 30', depending upon night temperatures and wind direction. Dissolved oxygen concentrations remained high throughout the winter, ranging from 10.2-11.3 mg/L at 1 meter depth.

Compared to the original turbine/compressor unit, the new spring-loaded compressor and shorter turbine blade do require a stronger wind for start-up and a steady 12 to 14 mph wind to begin pumping air. Windgen Ltd. has calculated that at a wind speed of 14.3 mph this compressor is pumping 10 cfm and at 21 mph, 27 cfm of air.

In January, with 2 to 3 inches of ice cover and a steady 14 mph wind, it took only 30 minutes for the air bubbles produced by the turbine and diffusor hoses to begin cracking and melting the ice cover. Within 4 hours, 60' x 20' and 50' x 15' areas were opened respectively in two 1-acre test ponds.

This summer we will aerate a third pond in an attempt to further evaluate the performance and possibilities of this single wind turbine/compressor aeration unit.

Projected Completion Date

N/A

Title: Wind and Solar Energy Feasibility Study

Performing Organization: Southeastern Illinois College

Principal Investigator(s):
Brittain A. Blair
Sam Porter
Jeff Grasf
Southeastern Illinois College
Harrisburg, Illinois 62946
(618) 252-6376

Sponsoring Organizations:
Southeastern Illinois College
Illinois Department of Adult, Vocational and Technical Evaluation

Project Location: Harrisburg, Illinois

Project Summary

As conventional energy costs and pollution levels continue to increase, so does the energy consumer's attempt to find and implement workable, efficient, and environmentally safe alternative energy methods. It is because of such an energy-awareness movement that Southeastern Illinois College, a leader in renewable fuels production and co-product utilization, feels the growing responsibility to expand its treatment of alternative energy technologies by offering seminars, workshops, and courses within the framework of a larger alternative energy vocational education program. Such a program would teach the energy conscious layperson and the career student studying alternative energies how to design, assemble, install, maintain, troubleshoot, and repair basic, affordable, and practical alternative energy systems. Also included in the program would be instruction in energy economics, calculating the alternative energy user's energy savings.

Before a program of this type can be initiated, however, a feasibility study based on a close comparative examination of a number of established exemplary alternative energy programs throughout the Midwest should be conducted to determine if indeed Southeastern has the capacity to offer an alternative energy vocational training program. Furthermore, the feasibility study would assess the community's need and desire for training of this sort.

This project will provide DAVTE, Southeastern, and ICCB with reliable information from which decisions can be made regarding the future funding and development of an alternative energy vocational training program at Southeastern.

Projected Completion Date

June 30, 1984

WASTE HEAT AND MATERIALS RECOVERY

Title: Energy and Materials Resource Recovery from Industrial Wastewaters

Performing Organization:	Renewable Resource Systems Section Systems Engineering and Technology Group Energy and Environmental Systems Division Argonne National Laboratory Argonne, IL 60439
Principal Investigator(s):	Barbara J. Broomfield, F. Kremer, M. Torpy, and L. Fradkin EES 362-2B Argonne National Laboratory Argonne, Illinois 60439
Sponsoring Organization:	Office of Industrial Programs (OIP) U. S. Department of Energy (DOE)
Project Location:	Argonne National Laboratory Argonne, IL 60439

Project Summary

The purpose of this program is to develop promising technologies for producing high quality fuels and recovering useful materials from industrial wastewaters. Major emphasis is placed on developing new technologies that are economically and technically feasible and have widespread application. The program's principal activity is to initiate, monitor and evaluate long-term, high-risk generic research and development projects that will be commercialized by the private sector. Participation and cost-sharing by industry and other government agencies in projects is a high priority. Other supporting efforts include: technical, economic and policy assessments; proposal review; liaison activities with the public and private sectors; and information dissemination.

Four basic areas of research and development activities have been established: biological, thermal, acid/metal recovery, and reuse, and hazardous waste treatment and recovery technologies. Research and development projects have been initiated in each as follows:

Biological

- ° Project to study the degradation of polyaromatic hydrocarbons and halogenated aromatics under strict anaerobic conditions. The objective of this research is to determine the mechanisms of bacterial adaptation to the priority pollutants, define the role of enzymes and DNA in acclimation and evaluate the use of fixed film anaerobic reactors for treating the complex organic chemicals and petroleum refining wastewaters. Performed at ANL.

- ° Project to identify and compare the attached anaerobic films in several reactor types to investigate their biological, chemical, and physical characteristics. The research seeks to determine appropriate applications, performance expectations, and to decrease reactor start-up time. Cosponsored by National Science Foundation and State of Massachusetts; work performed at the University of Massachusetts.

- A Notice of Program Interest (NPI) requesting innovating proposals employing biological or enzymatic methods to recover energy and useful materials from industrial wastes has been issued by DOE/OIP. DOE is seeking novel, high-risk research and development of biological or enzymatic treatment technologies that have exceptional potential for saving energy and recovering useful materials and which are not pursued expeditiously by the private sector due to high technical and/or economic risk. ANL is serving as the technical advisor, proposal evaluator, and technical monitor for activities under this NPI. Proposals were evaluated; contract awards are scheduled to be made in July 1984.

Thermal

- Project to recover useful materials and energy from high metallic sludges using pyrolysis technology. The metals coalesce into a rough ingot which can be recycled and the organic heat value recovered from hot exhaust gases. Performed at Purdue University.

- Project to recover energy from oily sludges produced by oil refineries using pyrolysis technology. Large quantities of sludge containing up to 25 percent or more oil and have accumulated at many refineries. Much of this sludge is potentially hazardous and presents a difficult disposal problem. Approximately 100 million Btu/hour can be extracted from this sludge through pyrolysis leaving a much smaller amount of residue. To be cosponsored and performed at Amoco Research Center; scope of work and funding requirements currently under development and negotiation.

Acid/Metal Recovery and Reuse

- Project to recover strategically important metals as well as nitric acid and hydrofloric acids from spent stainless steel pickle liquors. In the 70 million gallons of pickle liquors produced annually, 1,600 tons of chromium and nickel are currently lost. The acids themselves, products of extensive and energy-intensive processes, are currently disposed of with the metals in landfills at a cost in excess of $7.5 million annually. Initial technology evaluation and process selection is the first phase of this research. Cosponsored by the International Nickel Company and the American Iron and Steel Institute; work performed at the Inco Alloy Products Company Research Center. Detailed scope of work and funding requirements are presently being developed.

Hazardous Waste Treatment and Recovery Technologies

- ANL is interested in applying our knowledge of biological and thermal treatment technologies to treat and recover valuable energy or materials from hazardous industrial wastes. Initial discussions on feasible projects have begun with DOE, the Department of Defense, and industry. Cost shared, jointly sponsored research and development projects are being solicited to develop effective energy and economically efficient treatment/recovery processes. Interested parties are urged to contact the principal investigator for exploratory discussions concerning specific projects or wastes.

Related Publications

Broomfield, B., "The Influence of NPDES Permit Requirements on wastewater treatment costs at selected DOE facilities," Final Draft, completed in February 1983. Publication as an ANL technical memo in progress.

Kremer, F., B. Broomfield, and L. Fradkin, "Energy and Materials Recovery from Industrial Wastewaters," Argonne National Laboratory Report ANL/CNSV-44, Argonne, IL (November 1983).

Kremer, F. V., and B. Broomfield, "Energy conservation in the treatment of industrial waste streams," presented at the Sixth International Symposium of the International Association of Science and Technology for Energy Development (LASTED), Energy '83, San Francisco, CA, May 16-18, 1983.

Kremer, F. and B. Broomfield, "Metals recovery from electroplating wastewaters," Industrial Waste, eds. J. Alleman, J. Kavanagh, Ann Arbor Science, Ann Arbor, MI, June 1982.

Kremer, F. and B. Broomfield, "Energy and materials recovery options for the textile industry," published in Proc. of the 37th Industrial Waste Conference, Ann Arbor Science Publishers Inc., Ann Arbor, Mich., May 1982.

Davis, M. J. and M. F. Torpy, "Technical issues associated with water quality-based pollution controls," Argonne National Laboratory, Argonne, IL, 1982.

Torpy, M. F., A. B. Bishop, and R. Narayanan, "Identifying environmentally acceptable least-cost pollution control systems," Journal of Environmental Management, 15:287-300, 1982.

Broomfield, B., "Program Overview: Energy and materials recovery from industrial wastewaters", a report prepared and presented at DOE's Waste Products Utilization Branch Review on December 15, 1982.

Broomfield, B., "Future directions and innovations for energy conservation in wastewater treatment," published in Proceedings of the Alabama Association for Water Pollution Control Seminar, Energy Optimization in Wastewater Treatment, Montgomery, Ala., February 1981.

Kremer, F., "Bacterial adaptation to an industrial wastewater," Proceedings of the Symposium on Energy from Biomass and Wastes, Institute of Gas Technology, Chicago, IL, January 1980.

Kremer, F. and L. Fradkin, "Bioconversion of an industrial waste to methane gas," Proceedings of the 3rd Miami International Conference on Alternative Energy Sources, Clean Energy Research Institute, Coral Gables, Florida, December 1980.

Fradkin, L. and F. Kremer, "Use of a chrome tannery solid waste for improving anaerobic digestion," Proceedings of the 35th Purdue University Industrial Waste Conference, ed. J. Bell, Ann Arbor Science, Ann Arbor Mich., May 1980.

Kremer, F. and L. Fradkin, "Acclimation of anaerobic digesters to industrial wastes with the addition of metals without loss of methane production," Proceedings of the Energy Optimization of Water and Wastewater Management for Municipal and Industrial Applications Conference, U. S. Department of Energy, Argonne National Laboratory, December 1979.

Torpy, M. F. and E. J. Middlebrooks, "Plating and cyanide wastes," Water Pollution Control Federation Journal, 48(6):1295-1299, 1976.

Fradkin, L. and S. Barisas, "Technologies for treatment, reuse, and disposal of PCB wastes," Argonne National Laboratory Report ANL-EES-TM-168, Argonne, IL (January 1982)

Fradkin, L. and S. Barisas, "Waste management options for PCBs," presented at the 14th mid-Atlantic Industrial Waste Conference, University of Maryland. (June 1982).

Fradkin, L., S. Barisas, and D. Streets, "Economic impact of pending regulations on the disposal of hazardous and nonhazardous energy wastes," presented at the International Agency of Science and Technology for Energy Development (IASTED), Energy '83 Conference, San Francisco, Calif. (May 1983).

Fradkin, L. "Anaerobic biotechnology-hazardous wastes, "Expert Testimony to the Illinois Hazardous Waste Task Force Joint Committees on Alternate Technologies and Economics, Rockford, IL (October 15, 1983).

Kremer, F. "Recovery of metals from waste streams," Expert Testimony to the Illinois Hazardous Waste Task Force Joint Committees on Alternate Technologies and Economics, Rockford, IL (October 25, 1983)

Title: Plastic Heat Exchangers for Waste Heat Recovery

Performing Organization: Argonne National Laboratory

Principal Investigator(s): R.E. Holtz and P.D. Roach
Argonne National Laboratory
Building 330
9700 S. Cass Avenue
Argonne, Illinois 60439 (312) 972-4465
(312) 972-8146

Sponsoring Organization: U.S. Department of Energy

Project Location: Argonne, Illinois

Project Summary

Currently, considerable energy in furnace and boiler exhaust gases is wasted (discharged to the atmosphere) because: (1) condensation of acid associated with sulphur in the fuel can produce corrosion and fouling problems that quickly destroy conventional metal heat exchangers, and (2) the cost of exotic metal heat exchangers that would resist the corrosion is prohibitive. The development of plastic heat exchangers for the recovery of low-temperature waste heat could solve both the cost and corrosion problems.

The acid condensation is only a problem in the temperature range below approximately 300°F, where numerous plastics perform well. Using conventional metal heat exchangers in this temperature range leads to corrosion, fouling and eventual destruction of the heat exchanger. But plastics can be used to halt this process and allow economical recovery of the waste heat. The plastic, besides preventing corrosion and the associated fouling, also tends to resist the accumulation of particulate fouling. This is a result of the unique surface properties (slipperiness) of the plastics.

A survey of available plastics has led to the selection of the following plastics as good candidates: Teflon TFE (tetrafluorethylene), Teflon FEP (fluorinated ethylene propylene), Teflon PFA (perfluoroalkoxy), Ryton PPS (polyphenylene sulfide) and Kynar PVDF (polyvinylidene fluoride). These have been tested for use as corrosion barriers in a specially constructed apparatus which exposes the test pieces to an atmosphere of hot sulfuric acid vapor. An additional phase of testing has exposed the test pieces to temperatures as high as 700°F to determine thermal stability of the plastic films.

Early results of the testing have shown that both Teflon PFA and Ryton PPS give a good combinatoin of corrosion resistance, high-temperature stability and ease of fabrication. Ryton has the advantage of being substantially cheaper. Coating thicknesses in the range 0.010 to 0.020 inch give good resistance to corrosion and fouling, while causing only minimal degradation of heat transfer performance. Upper use temperatures for these plastics are approximately 500°F, giving them a wide range of application.

Work is continuing with the testing of these and other plastics applied in different thicknesses. The next step will be the construction and testing of a prototype heat exchanger in cooperation with an industrial user. This phase will demonstrate the long life and thermal efficiency that can be expected from such a unit.

Projected Completion Date

March 1984

Related Publications

Roach, P.D. and R.E. Holtz. "Tests on plastics as corrosion barriers for flue-gas heat recovery," Proceedings of Symposium on Condensing Heat Exchangers, Atlanta, Georgia, March 1982.

Title: Waste Heat Recovery Fluids for Heavy-Duty Transportation Bottoming-Cycle Systems

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Ken L. Uherka and John L. Krazinski
Argonne National Laboratory
Building 330
9700 S. Cass Avenue
Argonne, Illinois 60439 (312) 972-7814
(312) 972-5884

Sponsoring Organization: U.S. Department of Energy

Project Location: Argonne, Illinois

Project Summary

Bottoming-cycle systems offer the potential for using the waste heat contained in the exhaust gases of diesel engines used in highway, railway and marine transportation systems. The major advantage of bottoming-cycles for such applications is their high recovery efficiencies for the temperature range associated with the rejected waste heat from transportation power systems. The bottoming-cycle uses the rejected waste heat to vaporize the working fluid (usually an organic fluid), which then expands through a turbine and produces useful power. The bottoming-cycle in its several forms improves fuel economy by converting exhaust heat from the prime engines into shaft horsepower. This horsepower (hp) increase permits use of the prime mover at a lower hp setting, permits an increased payload to be carried or increased velocity to be developed, or can be used to satisfy other power needs at no increase in fuel usage. For example, increased fuel savings of 8 to 15 percent are realizable through addition of an organic Rankine bottoming cycle (ORBC) to a diesel engine.

While substantial data exist concerning bottoming-cycle systems, much of the available information applies to specific design concepts. There is a need for an overall assessment of waste heat recovery technology for highway, railway and marine transportation systems. Available data concerning both organic and inorganic fluids, which can be used as the heat-transport medium in bottoming-cycles, need to be updated and evaluated with respect to state-of-the-art knowledge concerning thermodynamic properties, stability, materials compatibility, safety characteristics, physical/chemical properties and other factors of interest. For those fluids for which design information is unavailable or insufficient, research needs must be identified and pursued in order to establish the technology base for developing improved waste-heat-recovery systems. A complete characterization and understanding of candidate working fluids are a required first step in establishing optimal bottoming-cycle systems for the spectrum of prime movers used in the transportation sector.

The objective of this program is to determine the properties and operating characteristics of heat-recovery fluids for a variety of bottoming-cycle systems. It is intended to identify the optimum working fluids for bottoming cycles used as an adjunct to diesel engines in heavy-duty long-haul trucks, to diesel-powered marine push-tow boats, and to diesel-powered locomotives. The goal is to establish a technology base for cost-effective bottoming-cycle systems and, consequently, shorten the lead time for their future commercialization in the transportation sector.

The program has been divided into three major tasks. These tasks are summarized below:

° Task 1. Bottoming-Cycle Requirements. Determine fluid property and other critical requirements for transportation bottoming-cycle systems on the basis of industrial R&D experience to date. This involves collecting data from present and former contractors on: prime engine characterization, bottoming-cycle constraints, fluid characteristics, materials, thermodynamic requirements, cost aspects and other pertinent factors.

° Task 2. Candidate-Fluids Selection. Candidate fluids will be identified, selection criteria derived on the basis of requirements establish in Task 1, and the most promising fluids characterized in detail for long-haul trucks, railway locomotives and marine push-tow vessels. Participation by chemical manufacturers and other industries will be insured by subcontracting a major portion of the Task 2 effort to industry sources.

° Task 3. Fluids Comparative Evaluation. The methodology and simulation models necessary for thermodynamic and economic analyses of transportation bottoming-cycle systems will be established. Cost/benefit assessments of the candidate fluids selected in Task 2 will be performed. The heat-recovery fluids will be priority ranked for each transportation system of interest.

The Task 1 effort has now been completed. Work is continuing on the selection of candidate working fluids in Task 2. It is expected that one or two industrial organizations will participate in the fluid selection process.

Expected Completion Date

October 1984

Title: Organic Rankine Cycle (ORC) Waste Heat Energy Conversion System

Performing Organization: Sundstrand Energy Systems

Principal Investigator(s): Department 853
4747 Harrison Avenue
P.O. Box 7002
Rockford, IL 61101 (815) 226-7991

Sponsoring Organizations: A field test program was jointly funded by Sundstrand and the U.S. Department of Energy

Project Location: Development system in Rockford, IL
7 systems installed at various sites

Project Summary

Many efforts are currently being pursued to develop and implement new energy technologies aimed at meeting our national energy goals. The use of organic Rankine cycle engines to generate power from waste heat provides a near term means to greatly increase the fuel utilization efficiency of many processes. Sundstrand has developed an organic Rankine cycle unit to recover energy from various waste heat sources. A field test program was jointly funded by Sundstrand and the U.S. Department of Energy. As part of this program, units were placed in the field to demonstrate the economic viability and reliability of the equipment in commercial and industrial applications.

The Sundstrand Organic Rankine Cycle (ORC) Waste Heat Power Conversion System is intended to be a universal bottoming cycle that can convert the energy in waste heat streams into usable shaft power. The nominal rating of the unit is 750 KW or 1,100 HP. By varying the configuration of the waste heat recovery vaporizer, the unit can accommodate most gaseous waste heat streams that have a temperature between 600°F and 1,200°F with sufficient flow. The vaporizer can also be designed for liquid or condensing waste heat streams with temperatures above 500°F, which makes it well suited for solar power systems using concentrating collectors.

A diverter valve directs the waste heat stream through the vaporizer. Working fluid is boiled in the vaporizer. Saturated vapor expands through the turbine, generating mechanical power. This expansion process causes the working fluid to become highly superheated. The vapor is desuperheated by passing it through a regenerator, then condensed and collected in a reservoir. A pumping system increases the working fluid pressure and sends it to the regenerator for preheating. The preheated liquid then flows to the vaporizer, completing the cycle.

The unit is designed for unattended operation. In most applications even the startup and shutdown can be performed totally automatically.

Projected Completion Date

Ongoing

Related Publications

"Power generation through waste heat recovery." Sundstrand brochure 9014824/0681.

"Power generation from waste heat using organic rankine cycle systems." Sundstrand paper 9021185/0681.

"Fluid selection and optimization of an organic rankine cycle waste heat power conversion system." ASME publication 78-WA/Ener-6 (copies available from Sundstrand).

Title: Surface-Heating Greenhouses with Power Plant Waste Heat Water

Performing Organization: University of Illinois-Champaign

Principal Investigator(s): Harry J. Rand
Illinois Power Company
500 South 27th Street
Decatur, Illinois 62525 (217) 424-6872

Sponsoring Organization: Illinois Power Company

Project Location: Baldwin Power Station
Baldwin, Illinois

Project Summary

An aluminum-framed glass greenhouse was constructed at the Baldwin Power Plant near St. Louis. The outside surface of this greenhouse was heated by flowing power plant discharge water over it. The water was applied at the ridge and allowed to run over the roof and sidewalls and into gutters where it was returned to the power plant's cooling water discharge canal.

One season's heating performance data and resulting conclusions are presented. These results show that surface heating reduced conventional heat requirements by one-third on the test greenhouse. However, when these results are projected to a commercial greenhouse the heating energy costs can be reduced by 67 percent. These cost savings would be 28 percent if 5°C cooler water were used and 90 percent if 5°C warmer water were used.

Projected Completion Date

Ongoing for demonstration only
Data collection stopped - May 1982

Related Publications

Walker, Paul N. and Harry J. Rand. "Surface heating greenhouses with waste heated water." Available from: Illinois Power Company.

Walker, Paul N. "Surface-heating greenhouses with power-plant cooling water." 1978 Winter Meeting - American Society of Agricultural Engineers, Paper Number 78-4518.

Walker, Paul N., S.S. Hazarus and J.B. Braden. "Surface-heating greenhouses: microeconomics. American Society of Agricultural Engineers, St. Joseph, Michigan, February 1981.

Walker, Paul N. and John D. Wells. "Surface-heated greenhouse performance." American Society of Agricultural Engineers, St. Joseph, Michigan, December 1980.

Title: Recovery Heat Exchange to Conserve Energy in Lumber Drying

Performing Organization:	Hardwood Processing Project North Central Forest Experiment Station Forest Service U.S. Department of Agriculture
Principal Investigator(s):	Howard N. Rosen Forest Service, USDA Forestry Sciences Laboratory Southern Illinois University Carbondale, Illinois 62901 (618) 453-2318
Sponsoring Organization:	United States Department of Energy
Project Location:	Wood Processing Pilot Plant Carterville, Illinois

Project Summary

By far the greatest single use of energy in the primary processing of solid wood products is drying, where 60 to 70 percent of the total energy for manufacturing is used. Presently, the lumber industry in the United States requires approximately 8 x 10^{13} Btu/yr. A 10 percent reduction in this requirement could save $24 million each year based on a cost of \$3/10^{5} Btu for energy. Solid wood products are generally dried in large batch or continuous kilns, where heat is applied to remove the water from the wood. The water vapor leaves the dryer through stacks in the roof of the kiln, where hot, humid air is vented directly to the atmosphere. Since 60 to 80 percent of the input energy to the kiln is removed through the vents, recovery from this stream seems a viable area for further research.

The overall objective of this project is to evaluate the technical feasibility of providing a conventional lumber kiln with a recovery heat exchanger which is capable of using the vent stream from a pressure steam lumber dryer. This main objective can be subdivided into several secondary ones:

1. to provide recovery heat at a minimum of 15 percent of the total energy required in the conventional kiln;

2. to provide design data such as temperature gradients across the heat exchanger, air flow through the heat exchanger, steam temperatures and pressures entering the heat exchanger, to permit potential users to assess the applicability of recovery heat exchange to their use; and

3. to compare shrinkage and degradation of pressure steam-dried lumber to that of conventional kiln-dried lumber.

Green 4/4 yellow-poplar and silver maple will be dried in a 100 board foot capacity pressure steam dryer. The vent stream of the pressure steam dryer will provide part of the heat load for drying green 4/4 yellow-poplar and black cherry in a 600 board foot conventional dry kiln, which has a recovery heat exchanger located inside the kiln structure. The energy savings as a result of using the recovery heat exchanger; equipment operating data such as temperatures, pressures, air and steam flow rates, electrical consumption of fans and heaters, and humidities; and lumber shrinkage, moisture content and degradation will be determined.

Projected Completion Date

Winter 1984

Related Publications

Rosen, H.N. "Energy requirements in high temperature and conventional kilns." Proceedings of the Symposium on High Temperature Drying of Hardwoods, March 22, 1979, New Albany, Indiana, pp. 41-54.

Rosen, H.N. "High temperature initial drying of wood: potential for energy recovery." For. Prod. J. 30(1):29-34, 1980.

Rosen, H.N. "Kiln size affects energy required to dry lumber." U.S. Dept. Agric. For. Ser. Res. Note NC-256, 1980, 2 pp.

Kent, A.C., H.N. Rosen and D.A. Crotty. "Energy conservation in wood dryers using vent air energy recovery devices." For. Prod. J. 31(2):43-49, 1981.

ENERGY STORAGE

Title: Advanced Lead-Acid Batteries for Electric Utility Load-Leveling Applications

Performing Organization: Argonne National Laboratory

Principal Investigator(s): Dr. N. P. Yao/Dr. J. F. Miller
Chemical Technology Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 (312) 972-4507

Sponsoring Organization: United States Department of Energy
Division of Energy Storage Systems

Project Location: Argonne, Illinois

Project Summary

This project encompasses the research, development and demonstration of advanced lead-acid batteries for electric utility load leveling. The objective of this project is to advance the lead-acid technology so that the cost and performance for a battery will be acceptable to the electric utility industry; key goals are to increase battery life from 2,000 to 4,000 cycles and to reduce initial battery cost from $150/kWh to $90/kWh. The major development efforts have been subcontracted, on a cost-sharing basis, with battery manufacturers who have developed the background technologies. Verificational testing and parametric evaluation of prototype batteries are being conducted at Argonne's National Battery Test Laboratory (NBTL). Limited technical support is also provided by a research group at Argonne.

Major Findings

Exide Management and Technology Co. completed a 41-month effort to develop advanced battery technology for energy storage under a cost-shared R&D contract. In this program, Exide examined the effects of changing battery design parameters such as plate thickness, active material density, acid volume and density, separator material, and grid alloy. To evaluate the proposed changes as quickly as possible, three types of accelereated lifetime tests were used: sustained overcharge cycling, rapid shallow cycling, and deep cycling. For the latter test, cells were deep cycled (80 percent depth of discharge) for two cycles per day at 70°C. Each cycle under these conditions has been found to be equivalent to approximately six cycles under normal conditions. Over 6,000 equivalent cycles were achieved by 1,800-Ah cells using this accelerated test regime. The sustained overcharge test, which evaluates positive-grid corrosion, identified a grid alloy that is suitably corrosion resistant for a battery to achieve 4,000 deep cycles. The shallow cycling test was employed to evaluate the rate of shedding of positive active material. The 200-Ah cells containing full-size plates completed 15,000 shallow cycles. Based upon the results obtained in these accelerated tests, 12 full-size (3,500-Ah) cells--comprising one six-cell and two three-cell modules--were constructed by Exide and delivered to NBTL for testing.

Argonne awarded another industrial R&D contract in this project to C&D Batteries in 1979. At C&D Batteries, 150 test cells with various design factors projected to increase cycle life and decrease cost were designed, fabricated, and put on test. The C&D Program was discontinued in March 1981 due to funding limitations. Although insufficient testing had been accomplished to be able to project the 4,000 cycle goal, 3,000 cycles could reasonably be projected as possible. A cost and design study by C&D Batteries indicated an OEM battery cost of 76-91 $/kWh.

At Argonne's National Battery Test Laboratory (NBTL), testing of advanced load-leveling batteries was initiated in April 1982. The test facility is a computer controlled laboratory which provides 24-hour-a-day operation. In testing to date at NBTL, the Exide batteries designed for load-leveling applications have operated reliably with performance exceeding design goals. Over 400 charge/discharge cycles have been imposed to date on an Exide six-cell battery with a capacity of 42 kWh. In addition, parametric testing and evaluation of two three-cell batteries (21 kWh each) have been conducted; the effects of varying charge and discharge rates have been evaluated. Application tests, using simulated power demands for utility load-leveling, have also been conducted.

Projected Completion Date

Ongoing project contingent upon continued technical advancements and available funding support.

Related Publications

Miller, J.F., D.O. Corp, E.R. Hayes, F. Hornstra, and N.P. Yao, "Testing and evaluation of advanced lead-acid batteries for utility load-leveling applications," Proceedings of the 18th Intersociety Energy Conservation Engineering Conference, Orlando, FL, August 21-26, 1983, (accepted for publication).

Exide Management and Technology Co., "Final report on research development and demonstration of advanced lead-acid batteries for utility load-leveling," Argonne National Laboratory Report ANL/OEPM-83-6, (in preparation).

C&D Batteries Division of Eltra Corp., "Final summary report--research development, and demonstration of advanced lead-acid batteries for utility load leveling," Argonne National Laboratory Report, ANL/OEPM-81-15, March 1982.

Varta Batterie Co., "Cost/design study and fabrication/testing of a 300-W gas recombination device for utility lead-acid cells," Argonne National Laboratory Report, ANL/OEPM-82-4, May, 1982.

Meighan, R.M., D.R. Green, and C.W. Flesichmann, "Advanced lead-acid load leveling battery," Progress in Batteries and Solar Cells, Vol. 3, 1981 (JEC Press Inc.)

Chreitzberg, A.M., T.M. Noveske, and W.P. Sholette, "Accelerated deep cycling test for lead-acid load-leveling cells," Extended Abstracts, Electrochemical Society Meeting, October 11-16, 1981, Denver, CO, pp. 11-12.

Noveske, T.M. and A.M. Chreitzberg, "Continuous overcharge accelerated positive grid corrosion test on lead-antimony pasted flat plate cells," Extended Abstracts, Electrochemical Society Meeting, October 11-16, 1981, Denver, CO, pp. 13-15.

Sklarchuk, J.C. and A.M. Chreitzberg, "Accelerated positive material shedding test for pasted flat plate lead-acid cells," Extended Abstracts, Electrochemical Soc. Meeting, October 11-16, 1981, Denver, CO, pp. 16-17.

Title: Aqueous Mobile Battery Program

Performing Organization: Argonne National Laboratory (ANL)

Principal Investigator(s): Dr. N. P. Yao/Mr. C. C. Christianson
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 (312) 972-4507

Sponsoring Organization: United States Department of Energy
Division of Electric & Hybrid Vehicles

Project Location: Argonne, Illinois

Project Summary

The Aqueous Mobile Battery Program carries out research and development directed towards improved lead-acid and nickel/iron batteries for future applications in electric vehicles. The work is part of DOE's Electric and Hybrid Vehicle Program implemented in response to Public Law 94-413, mandated by Congress in September 1976, and later amended by Public Law 95-238 in March 1978.

The Aqueous Mobile Battery Program is conducted by ANL's Office for Electrochemical Project Management (OEPM). The program utilizes an industry-based approach whereby industrial subcontractors carry out a major part of the battery technology development with project management (including supporting technical assistance as required) provided by ANL/OEPM. Performance and life verificational testing of industry-developed technology is performed by ANL's National Battery Test Laboratory (NBTL). ANL/OEPM also closely coordinates the program activities with those of the major electric vehicle developers and users.

ANL/OEPM initiated eight major industrial subcontracts for battery R&D early in 1978: three for lead-acid batteries, two for nickel/iron batteries, and three for nickel/zinc batteries. Each contractor pursued a parallel, but differing technical approach towards meeting the program objectives. In early FY 1982, a major programmatic decision was implemented when the number of battery R&D contractors was reduced to three: Globe Battery Division of Johnson Controls, Inc. for the lead-acid battery, and Westinghouse Electric Corp. and Eagle-Picher Industries, Inc. for the nickel/iron battery. Further engineering development of the nickel/zinc battery has been halted until an adequate solution to its limited life can be found. This reduction in number of contractors has allowed available resources to be focussed on the most promising technologies.

Program goals have been established to provide an electric passenger car with a range between battery charges of 100 miles in urban stop-and-go driving and acceptable performance, life, and cost. Since the inception of this program, significant progress has been achieved with lead-acid and nickel/iron batteries towards meeting these goals. The projected range of an electric car has been increased from 51 miles with perviously available batteries to 80 and 95 miles, respectively for these improved lead-acid and nickel/iron batteries. In addition the battery life in the car is expected to be increased by a factor of 3.0 for the improved lead-acid and 6.0 for the improved nickel/iron batteries when compared to previously available batteries. Additional improvements in the energy storage capability (vehicle range) of these battery systems, as well as lower cost for the nickel/iron battery, are being sought.

At present, there are three major areas of activity within the program. One area of activity is that associated with the Technology R&D. This includes the subcontracted battery R&D plus the post-test analysis conducted at ANL. The second major area of program activity is the Battery Application Tests, where battery performance and life are being determined in tests at the NBTL. The third major area of program activity is the Battery Application Studies. These studies encompass battery charging investigations, evaluation of the impact of motor speed controls on battery discharge behavior, and batery thermal modeling to develop proper battery thermal control systems.

The improved battery technology resulting from this R&D program has generated considerable interest among potential electric vehicle manufacturers and fleet operators. Major automotive manufacturers have purchased full-size lead-acid and nickel/iron batteries for testing and evaluation. Fleet operators have placed into operation several electric vehicles with these improved batteries to evaluate their performance.

Projected Completion Date

Ongoing project contingent upon continued technical advancements and available funding support.

Recent Related Publications

Baxa, M. S. and C. F. Weinlein, "Design of an innovative lead-acid battery for electric and hybrid vehicles," presented at Electrochemical Society Meeting, October 17-22, Detroit, MI.

Cook, G., et al., "Annual synopsis of Argonne's aqueous battery support research," ANL/OEPM-82-3, March 1982.

Corp, D., E. Berrill, D. Fredrickson, et al., "Peak power characteristics of improved electric-vehicle batteries," presented at 1982 Society of Automotive Engineers Congress, Detroit, MI, February 11-16, 1982.

DeLuca, W., A. Tummillo, F. Hornstra, et al., "Effects of pulsed-current discharge waveforms on lead-acid traction cell performance," presented at 1982 Society of Automotive Engineers Congress, Detroit, MI, February 11-16, 1982.

Eagle-Picher Industries, Inc., for Argonne National Laboratory, "Annual report for 1981 on research development, and demonstration of nickel-iron batteries for electric vehicle propulsion," ANL/OEPM-81-13, March 1982.

Globe Battery Division of Johnson Controls for Argonne National Laboratory, "Annual report for 1981 on research, development and demonstration of lead-acid batteries for electric vehicle propulsion," ANL/OEPM-81-10, March 1982.

Hill, L. G., C. M. Maca, and F. R. Wyant, "An evaluation of nickel, cobalt, lead, and zinc price and distributional flow changes assuming high commercialization of nickel-zinc and lead-acid electric vehicles," ANL/OEPM-82-1, January 1982.

Hornstra, F., C. Christianson, P. Cannon, et al., "The impact of regenerative braking on battery performance and energy cost in electric vehicles in urban driving patterns," *EVC Symposium VI Proceedings*, 1981.

Hornstra, F., and N. P. Yao, "Standard test procedures for electric-vehicle batteries at the national battery test laboratory," presented at 1982 Society of Automotive Engineers Congress, Detroit, MI, February 11-16, 1982.

Hudson, R., "The nickel-iron battery for electric vehicle propsulsion," *EVC Symposium VI Proceedings*, 1981.

Jorgensen, J. D., R. Varma, F. J. Rotella, et al., "Lead deficiency and hydrogen content in battery electrode B-Pb$_2$," *J. Electrochemical Society* 129 (8):1678-1681, 1982.

Lee, J., K. W. Choi, C. C. Christianson, and N. P. Yao, "Three-dimensional thermal modeling of EV batteries," presented at Electrochemical Society Meeting, Detroit, MI, October 17-22, 1982.

Liu, M., B. R. Faulds, G. M. Cook, and N. P. Yao, "Conductivity of KOH electrolyte supersaturated with zincate," *J. Electrochemical Society*, 128 (10):2049-2052, 1981.

Liu, M. B., G. M. Cook, and N. P. Yao, "Transient current distributions in porous zinc electrodes in KOH electrolyte," *J. Electrochemical Society*, 129 (2):239-246, 1982.

Liu, M. B., G. M. Cook, and N. P. Yao, "The relationship between electrolyte conductance and current distribution in porous zinc electrode in KOH electro- lyte," *J. Electrochemical Society*, 129 (b):1390-1392, 1982.

Liu, M. B., G. M. Cook, and N. P. Yao, "Vibrating zinc electrodes in Ni/Zn batteries," *J. Electrochemical Society*, 129 (5):913-920, 1982.

Liu, M., E. Rudnick, G. M. Cook, and N. P. Yao, "Mass transfer at longitudinally vibrating vertical electrodes," *J. Electrochemical Society*, 129 (9):1955-1959, 1982.

Maskalick, N. J. and E. S. Buzzelli, "Performance of nickel-iron cells related to electrolyte composition," presented at Electrochemical Society Meeting, Detroit, MI, October 17-22, 1982.

Miller, J. F., J. B. Rajan, F. Hornstra, et al., "Status of improved lead-acid, nickel/zinc batteries being developed under DOE's electric vehicle battery program," presented at Electrochemical Society Meeting, Detroit, MI, October 17-22, 1982.

Pierson, J. R., and C. E. Weinlein, "Development of unique lightweight high performance lead-acid batteries," presented at 13th International Power Sources Symposium, Brighton, England, September 17-30, 1982.

Rosey, R., "Westinghouse nickel-iron battery performance - 1981," EVC Symposium VI Proceedings, 1981.

Rosey, R., "Manufacturing techniques and cost analysis for nickel-iron batteries," presented at Electrochemical Society Meeting, Detroit, MI, October 17-22, 1982.

Swoboda, C. A., P. H. Cannon, F. Hornstra, et al., "Solid state high common-mode battery cell voltage scanner," ANL/OEPM-81-7, November 1981.

Thuerk, D., "Design of an efficient electrolyte circulation system for the lead-acid battery," presented at 30th Power Sources Symposium, Atlantic City, NJ, June 7-10, 1982.

Varma, R., G. Cook, and N. P. Yao, "Anodization and sulfation of tetrabasic-leadsulfate in sulfuric acid: in-situ monitoring of electrode surface phases by laser raman scattering," J. Electrochemical Society, 127 (5):1165-1168, 1981.

Varma, R., G. M. Cook, and N. P. Yao, "Raman spectrocopy for in-situ monitoring of electrode processes," ANL/OEPM-82-2, April 1982.

Weinlein, C. E., "Lead-acid battery performance and technology in commercial electric vehicle applications," presented at 9th Energy Technology Conference and Exposition, Washington, DC, February 16-18, 1982.

Westinghouse Electric Corp. for Argonne National Laboratory, "Annual report for 1981 on research, development, and demonstration of nickel-iron batteries for electric vehicle propulsion," ANL/OEPM-81-14, March 1982.

Yao, N. P., C. C. Christianson, T. S. Lee, et al., "DOE's electric vehicle battery program - status of improved lead-acid, nickel/zinc battery development in 1981," EVC Symposium VI Proceedings, 1981.

Yao, N. P., "U.S.A. EV battery programme," J. Power Sources, 7 (4): 317-329, 1982.

Title: Battery Testing and Evaluation

Performing Organization:	Argonne National Laboratory (ANL) National Battery Test Laboratory
Principal Investigator(s):	Dr. N. P. Yao/Mr. F. Hornstra Argonne National Laboratory 9700 South Cass Avenue Argonne, IL 60439 (312) 972-4507
Sponsoring Organization:	United States Department of Energy Division of Energy Storage Systems/ Division of Electric & Hybrid Vehicles
Project Location:	Argonne, Illinois

Project Summary

The National Battery Test Laboratory (NBTL) at ANL is a central facility for testing, evaluating, and studying batteries that are being developed. Batteries developed under DOE sponsored programs and those developed by private industry are tested in the NBTL. These batteries have three principal applications--electric vehicle propulsion, electric utility load leveling and solar energy storage.

The NBTL serves five key roles as follows:

- It serves as a facility for testing cells and batteries at various stages of development.
- It provides a centralized and independent facility for comparing and evaluating the performance of various types and brands of battery under uniform operating conditions.
- It permits the testing of battery performance under simulated operating conditions prior to application demonstration.
- It provides data for analysis and improvement.
- It serves as a facility for charge, discharge, and thermal studies.

Established in 1977, the NBTL became operational in 1978. It is computer automated to operate unattended around-the-clock. The facility has room for the simultaneous testing of about 70 batteries, each independently operated, under various environmental conditons and over a wide range of voltges and currents. Walk-in environmental chambers, a facility to test zinc/halogen batteries, and a facility to test high-temperature batteries have been incorporated. Individual cells, multicell modules, and full-sized battery packs are accommodated.

Since becoming operational, the NBTL has evaluated over 900 cells of various battery technologies. Performance-characterization assessments are conducted under a series of charge/discharge cycles with constant current, constant power, peak power, and simulated load profile conditions. Tests are also conducted to determine the cycle life of batteries under various operating and environmental conditons. Flexible charging algorithms are provided to accommodate the single needs of each battery system. In addition, facilities exist to provide special studies to explore and optimize charge procedures, to investigate the impact of unique load demands on battery performance, and to analyze the thermal management requirements of battery systems.

Scaling and normalization techniques developed and employed by the laboratory permit the evaluation of a cell, or a multicell module, as it would operate in a full-sized battery pack for the intended application. Thus, assessments of the potential for a particular battery technology can be made economically and early in a development program. As the technology under development matures, larger units, including full-sized battery packs are tested to evaluate system performance and reliability in a well instrumented and controlled environment. Prior to in-vehicle installation, batteries may be tested with the simulated, anticipated load requirements to assure system integrity and performance before the batteries are subjected to more expensive and visible tests in a vehicle.

In the NBTL, test voltages and currents are controlled and data recorded and analyzed by computers. Display systems instantly provide graphs of data or tabulations of the performance history of an individual battery. The results of the tests help establish standards for battery construction, maintenance, performance and safety, and determine which batteries are best suited for the application.

Significant Results

- Developed and implemented an analytical tool to normalize battery performance to minimize the impact of battery aging on the accuracy and reproductibility of test results.
- Discovered and quantified a phenomenon that suggests a direct relationship between the thermal response and energy density of a battery, i.e.,

$$\Delta T \propto Wh/kg.$$

- Measured and quantified the following benefits of regeneration braking on battery performance in electric vehicles:

  (1) Charge acceptance of the batteries during the pulse of charge current during regeneration braking is approximately 100 percent.

  (2) With regeneration braking, the batteries can extend the vehicle range 20 to 30 percent.

(3) No additional thermal burden is exhibited by the batteries as a result of operation with regeneration braking.

- Measured and determined the extent of the impact of SCR chopper, or switching transistor, type pulsed discharges on lead-acid batteries with the following results compared with equivalent DC discharges:

  (1) Lower available battery power and energy because of increased internal losses.

  (2) Elevated battery temperatures due to increased internal losses.

  (3) Internal losses, and external power, are independent of frequency of pulses.

  (4) The effects can be analyzed for lead-acid batteries on the basis of a simple equivalent circuit consisting of a fixed voltage and a series resistance.

  (5) Pulsed discharges appear not to have a major impact on lead-acid battery cycle life.

- Measured the inductance of lead-acid and Ni/Fe batteries with the following results:

  (1) The inductance of lead-acid batteries are generally comparable to, but less than, the inductance of the connecting cables.

  (2) The inductance of a Ni/Fe battery of equivalent size to a lead-acid battery has an order of magnitude of greater inductance.

  (3) The battery inductance must be taken into account in the design of battery power controllers to preclude damage by voltage transient induced by the inductance.

Projected Completion Date

Ongoing

Related Publications

Hornstra, F., E. Berrill, P. Cannon, D. Corp, D. Fredrickson, V. Kremesec, W. Lark, C. Swoboda, and C. Webster. "Results of simulated driving profiles in the testing of near-term electric vehicle batteries." Proc. EVC Expo '80 Conf., St. Louis, MO, May 20-22, 1980; Paper EVC No. 8034, Electric Vehicle Council, Washington, D.C. 1980.

Hornstra, F. "Simulated driving profiles in the testing of near-term batteries at ANL." Electric and Hybrid Vehicle Program Quarterly Report (January, February, March 1980). U.S. DOE Report DOE/CS-0026-10, pp. 14-16, May 1980.

Hornstra, F. "Peak power measurements at the national battery test laboratory." Electric and Hybrid Vehicle Program Quarterly Report (April, May, June, 1980), U.S. DOE Report DOE/CS-0016-11, pp. 14-15, August 1980.

Hornstra, F., E. Berrill, P. Cannon, D. Corp, D. Fredrickson, M. Genge, C. Swoboda, and N.P. Yao. "Test results of computer generated driving profile applied to near-term batteries." Proc. 30th Annual Conf. IEEE Vehicular Technology Soc. (Convergence 80), Dearborn, MI, September 15-17, 1980, Paper No. C-4-2, IEEE, New York, 1980.

Yao, N.P., C.C. Christianson, J.B. Rajan, T.S. Lee, R. Elliott, J. Miller, F. Hornstra, G. Cook, W. DeLuca, K. Choi, V. Kremesec, and J. Barghusen. "Development of near-term batteries for electric vehicles--summary report, October 1977 - September 1979." ANL/OEPM-80-5.

Christianson, C.C., N.P. Yao, and F. Hornstra. "Near-term batteries for electric vehicles, energy technology VIII." Proc. Eighth Energy Technology Conf., Washington, DC, March 9-11, 1981, Government Institutes, Inc., Rockville, MD, pp. 616-623, 1981.

Hornstra F., E. Berrill, P. Cannon, D. Corp, W. DeLuca, D. Fredrickson, L. Singer, C. Swoboda, C. Webster, C. Christianson, and N.P. Yao. "Battery testing results at the national battery test laboratory." Fourth U.S. Department of Energy Battery and Electrochemical Contractors' Conference, Washington, DC, June 2-4, 1981, U.S. Department of Energy Report CONF-8106412, pp. 65-71, 1981.

Hornstra F., C. Christianson, P. Cannon, D. Fredrickson, C. Swoboda, C. Webster, and N.P. Yao. "The impact of regenerative braking on battery performance and energy cost in electric vehicles in urban driving patterns." Proc. Electric Vehicle Council Symp. VI, Baltimore, MD, October 21-22, 1981; Paper EVC No. 8106. Also publ. in Electric Vehicle News 10(4):8-11, November 1981.

DeLuca W.H., R.L. Biwer, and N.P. Yao. "Effects of constant-current/constant-voltage charge parameters on lead-acid traction cell performance." Proc. 16th Intersoc. Energy Conversion Eng. Conf., Atlanta, GA, August 9-14, 1981, pp. 674-679, 1981.

Yao, N.P., C.C. Christianson, and F. Hornstra. "Prospects of advanced lead- acid, nickel/iron and nickel/zinc batteries for electric vehicle applications." Proc. 16th Intersoc. Energy Conversion Eng. Conf., Atlanta, GA, August 9-14, 1981, pp. 641-644, 1981.

Swoboda, C.W., P.H. Cannon, F. Hornstra, R.J. Kmiec, and N.P. Yao. "Solid-state high common-mode battery cell voltage scanner." ANL/OEPM-81-7.

Yao, N.P., C.C. Christianson, F. Hornstra, G. Cook, W. DeLuca, T. Lee, J. Miller, J. Rajan, and C. Swoboda. "Development of aqueous batteries for electric vehicle--summary report, October 1979 - September 1980." ANL/OEPM-81-5.

Corp, D., E. Berrill, D. Fredrickson, R. Hogrefe, L. Singer, C. Webster, C. Christianson, F. Hornstra, and N.P. Yao. "Peak-power characteristics of improved electric-vehicle batteries." Proc. of the 1982 SAE Int. Congress and Exposition, Detroit, MI, February 11-16, 1982, SAE/P-82/105, pp. 7-10, 1982.

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Hornstra F. NBTL test activities." Presented at the Fifth U.S. Department of Energy Battery and Electrochemical Contractors' Conf., Session VIII, Washington, DC, December 7-9, 1982.

Yao, N.P., C.C. Christianson, J. Rajan, T. Lee, J. Miller, F. Hornstra, G. Cook, W. DeLuca, J. Klinger, D. Poa, J. Waters, J. Lee, and J. Barghusen. "Development of aqueous batteries for electric vehicle--summary report, October 1980 - September 1981." ANL/OEPM-82-5, 1982.

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Title: Demonstration of a Lithium-Metal Sulfide Powered Fleet Electric Vehicle; Phase I - Battery Development and Submodule Demonstration

Performing Organization: Argonne National Laboratory (ANL)

Principal Investigator(s): Dr. N. P. Yao/Mr. A. A. Chilenskas
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Sponsoring Organizations: Electric Power Research Institute
Palo Alto, CA

Project Location: Argonne, Illinois

Project Summary

A program has been initiated by the Electric Power Research Institute (EPRI) to test the feasibility of using the Li-Al/FeS battery for electric vehicle propulsion. An important step addressed in this proposal is the testing of modules to develop the performance and design information needed for full-scale battery design.

This program provides for a module test in a high-efficiency insulated case. Such a case, developed under a DOE program, is on hand at ANL. To the extent possible, the design of the module and battery components such as the heating/cooling system, battery case plug, etc. will be based upon the Li-Al/FeS van battery concept design presently being developed under a DOE program. The EPRI program will provide information and hands on experience of use to the battery designers in the areas of insulated case development, heating/cooling subsystem design, cell modularization, and charger development.

Major Findings/Projected Completion Date

The first phase of the program was initiated at ANL on December 1, 1983. Ongoing project contingent upon successful testing of the Li-Al/FeS battery at the module level and available funding support.

Related Publications

Chilenskas, A.A., et. al. "Design Considerations for a Lithium-Aluminum/Iron Sulfide Electric Vehicle Battery." Proceedings of the 17th Intersociety Energy Conversion Engineering Conference, Los Angeles, CA. August 8-12, 1982. Institute of Electrical and Electronics Engineers, Volume 2, pp. 579-583.

Chilenskas, A.A., et. al. "Design Considerations for a Li-Al/FeS Battery for an Electric Van." SAE International Congress and Exposition, Detroit, MI. February 28-March 4, 1983. SAE publication SP-541, pp. 15-18. February 1983.

Title: Development of High Performance Li-Al/FeS Batteries

Performing Organization: Argonne National Laboratory (ANL)

Principal Investigator(s): Dr. N. P. Yao/Mr. A. A. Chilenskas
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 (312) 972-4507

Sponsoring Organizations: United States Department of Energy
Division of Electric & Hybrid Vehicles
U. S. Army, MERADOCM, Fort Belvoir, VA

Project Location: Argonne, Illinois

Project Summary

The Li-Al/FeS battery, invented at Argonne in 1973, has been developed to an early engineering stage by the U.S. Department of Energy, Division of Energy Storage. Present work, sponsored by the U.S. Department of Energy (Division of Electric and Hybrid Vehicles) and the U.S. Army, is directed to the development of the battery for use as a power source for electric vehicles. The applications presently being developed are a van battery for the U.S. Department of Energy and a fork-lift truck battery for the U.S. Army.

In addition to the applications mentioned, the successful development of this battery is expected to provide a power source for a wide range of electric vehicles including the passenger car as well as a stationary energy source for utility and solar systems.

Major Findings

° Full size electric vehicle cells have been tested at Argonne that have demonstrated energy storage and power characteristics about 2 to 3 times that of present-day lead-acid batteries and have demonstated the capability for very long cycle life (>500 cycles) under conditions of deep discharge.

° Small batteries (5 to 10 cells) have been tested and have achieved >250 deep discharge cycles.

° The engineering characteristics of the battery have been examined and show the battery system to be safe, rugged, capable of excellent electrical performance, and having the potential for very long life. These characteristics indicate that the battery is an excellent candidate for many applications including propulsion of electric vehicles.

Projected Completion Date

Ongoing

Related Publications

Barney, D.L. et al., "Recent progress in lithium/iron sulfide battery development." *Proceedings of the 15th Intersociety Energy Conv. Engineering Conference*, AM. Inst. Aeronautics and Astronautics, pp. 198-204, 1980.

Chilenskas, A.A. et al., "Engineering characteristics of secondary lithium/molten salt batteries." *Proceedings of the 30th Power Sources Symposium*, Atlantic, NJ, June 7-10, 1982.

Chilenskas, A.A. et al., "Design considerations for a lithium-aluminum/iron sulfide electric vehicle battery." *Proceedings of the 17th Intersoc. Energy Conv. Engineering Conference*, Los Angeles, CA, August 8-13, 1982, 2:579-584, 1982.

Title: Electric Vehicle Battery Testing and Development Program

Performing Organization: Argonne National Laboratory (ANL)

Principal Investigator(s): Dr. N. P. Yao/Mr. C. C. Christianson
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 (312) 972-4507

Sponsoring Organization: Electric Poweer Research Institute
Electric Transportation Program Office

Project Location: Argonne, Illinois

Project Summary

The improved lead-acid electric vehicle battery, recently developed under the sponsorship of the Department of Energy, is well suited to those electric vehicle applications where extended range is not a requirement. However, adequate information does not presently exist on this newly developed battery to allow proper application. The objective of this Electric Vehicle Battery Testing and Development Program is to obtain the needed data. These data include the effect on battery life of:

a) representative power demand vs. time profiles expected during vehicle use,

b) the long rest times after discharge encountered in order to take advantage of off-peak charging, and

c) the charging method and procedure used.

The program also carries out a performance and life test in the laboratory of a full sized electric vehicle battery system for the purpose of evaluating the life, reliability, maintenance needs and thermal behavior. In addition, a computer model will be developed which will permit prediction of the thermal behavior of the battery under various ambient operating conditions and thus permit design of the proper heating and cooling system for maintaining the battery temperature within the most desirable operating range over the full range of environmental temperatures expected in vehicle use. The program also investigates methods for further improvement in the performance of these batteries through more efficient utilization of the active material. The results of the program will provide information of the developers of batteries, chargers, drive trains and electric vehicles which will aid in design and development of improved components and systems for use in electric vehicles.

This program was initiated in early 1983. Results from the program will not be available until early 1984.

Projected Completion Date

March 30, 1984

Related Publications

None

Title: Soyland Compressed Air Energy Storage Facility

Performing Organization: Soyland Power Cooperative, Inc.

Principal Investigator(s): Richard R. Ruzich
Executive Vice President
Soyland Power Cooperative, Inc.
675 West Imboden Drive
P.O. Box A1606
Decatur, IL 62525 (217) 423-8000

Sponsoring Organizations: Soyland Power Cooperative, Inc.

Project Location: Pike County near Florence, Illinois

Project Summary

Soyland Power Cooperative, a rural electric generation and transmission cooperative in Decatur, Illinois, is planning to construct a 220 MW compressed air energy storage (CAES) plant to meet anticipated peak demand loads.

Energy storage by power companies is becoming increasingly important because it provides the capability of using off-peak power to supply peak period demands. A concept not yet commercialized in the United States, CAES uses modified combustion-turbine technology to produce electricity from about one-third the fuel required by conventional combustion-turbine systems.

Turbine systems have two phases. The first compresses air to enrich the combustion output of the later, power-producing combustion stage. In the second phase, the compressed air is mixed with fuel, in this case oil is combusted to generate electricity. In conventional combustion turbines about two-thirds of the power created in this way is required to keep the compression phase going.

The CAES system saves oil/gas fuel and makes better use of baseload coal or nuclear-fueled generators by separating the phases of the turbine process. During low-demand hours, the compression phase of the turbine process is driven by electricity produced by the utility's baseload plants. The compressed air produced by this procedure is stored, in this case in a rock cavern, at a pressure of about 55 to 60 atmospheres.

Later, as peak demand puts a strain on the utility's generating capacity, the compressed air is mixed with oil/gas fuel and released into the combustion phase of the turbine process, producing power. Since the compressor need not be powered at this point, virtually all of the energy produced by combustion can go toward electricity generation.

The result is three times the electricity from the same amount of gas- or oil-based fuels, more peak capacity for the grid with improved reliability, and better utilization of baseload generating facilities.

The CAES plant is designed for an 11-hour charging cycle during which time air will be compressed and pumped into a hard rock cavern. As air is forced into the cavern, 2,000 feet below ground, water is pushed upward into the surface water compensation reservoir. The head of water in the reservoir maintains a constant pressure in the cavern even as cavern volume increases with displacement of the water. The plant has an 11-hour power generation cycle. Due to the quick startup time for use of the stored energy (approximately 10 minutes) the unit can also be considered a spinning reserve in the case of an emergency.

Projected Completion Date

Indefinite

REGULATIONS, SURVEYS AND PLANNING

Title: Energy-Conserving Development Regulations: Monitoring and Evaluation of Eight Demonstration Projects

Performing Organization: American Planning Association
1313 East 60th Street
Chicago, IL 60637

Principal Investigator(s): Michael J. Meshenberg
Energy and Environmental Systems Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 (312) 972-3989

Sponsoring Organizations: U.S. Department of Energy

Project Summary

APA is conducting a research project to monitor and evaluate the work of eight communities preparing and adopting Energy-Conserving Development Regulations for Site and Neighborhood Design. (RFP No. 79-20-0007). APA will follow the work of each community and prepare several reports and guidebooks to disseminate the information for other communities to use in implementing more energy-efficient community and neighborhood design.

Preliminary data collection is underway.

Projected Completion Date

N/A

Title: Region V Community Energy Management Study and Workshop

Performing Organization:	American Planning Association 1313 East 60th Street Chicago, IL 60637
Principal Investigator(s):	Judith Holm U.S. Department of Energy Chicago Operations and Regional Office Argonne National Laboratory 9700 S. Cass Ave. Argonne, IL 60439 (312) 972-2410
Sponsoring Organizations:	U.S. Department of Energy
Project Location:	Chicago, Illinois

Project Summary

APA will conduct a survey of local governments in Federal Region V (the six-state midwest region) to ascertain: 1) local activities to save energy; and 2) what local governments need from state and federal agencies in terms of technical assistance. APA will design and conduct a workshop for state Energy Extension Service personnel from the six states. The workshop will present the survey findings to help EES staff members with local energy-conserving efforts and continuing needs for assistance.

The survey questionnaire is presently under design.

Projected Completion Date

N/A

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CALL FOR CONTRIBUTIONS

The Fourth Edition of "Current Alternative Energy Research and Development in Illinois" is scheduled for publication in December 1984.

All researchers are encouraged to submit summaries of alternative energy projects in the format of the listings in this publication to:

Ronald Swager
Alternative Energy Section
Illinois Department of Energy
and Natural Resources
325 West Adams
Springfield, Illinois 62706

Contributors already listed are asked to review their summaries and submit any updates, new findings or final results that may be appropriate.

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The topics covered have been limited to those concerned with the development of non-fossil, non-nuclear energy sources.

Included are projects in process in May, 1984 or that had been completed after November, 1983. It attempts to include projects performed by Illinois organizations, both within the state and out-of-state, and projects performed by out-of-state organizations at sites within Illinois.

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